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ILLUMINATING OPTICAL DEVICE, ALIGNER, AND EXPOSURE METHOD

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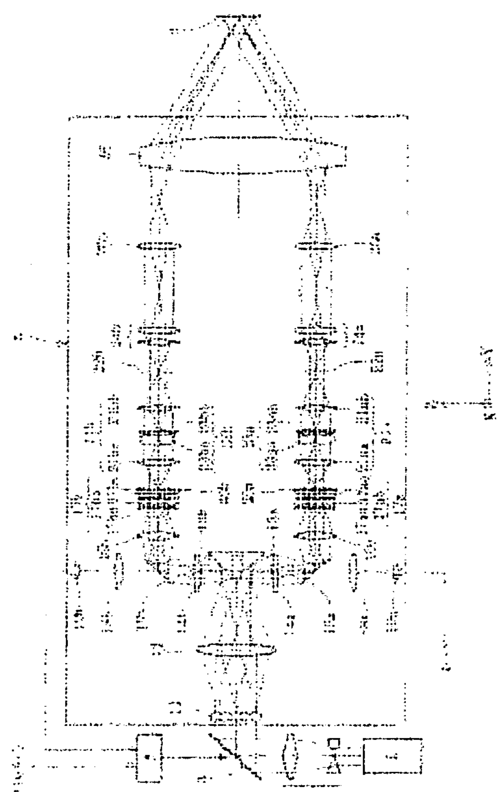
Abstract of JP 2005236088 (A)

PROBLEM TO BE SOLVED: To provide an illuminating optical device which can provide illumination conditions which are highly diverse regarding proper illumination conditions such as a secondary light source shape, light intensity and polarization state required for transferring a mask pattern with various characteristics truly when mounted on an aligner. . SOLUTION: The illuminating optical device illuminates an irradiation surface by optical flux from a light source (1). It has an illuminating pupil formation means (20 to 26, 6) for forming illuminating pupil distribution with light intensity distribution located in a first region, and light intensity distribution located in a second region on an illuminating pupil surface; and illuminating pupil control means (17, 23 and 24) for carrying out control for changing the shape of the first region and the shape of the second region independently from each other, and control for changing the polarization state of optical flux passing through the first region and the polarization state of optical flux passing through the second region independently from each other. ; COPYRIGHT: (C)2005,JPO&NCIPI



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CLAIMS

[Claim(s)]
[Claim 1]
In an illumination optical device which illuminates an irradiated plane by light flux from a light source,
The Lighting Sub-Division pupil means forming for forming the Lighting Sub-Division pupil distribution which has light intensity distribution located in the 1st field on an illumination pupil plane, and the light intensity distribution located in the 2nd field,
An illumination optical device provided with the Lighting Sub-Division pupil control means for performing control which changes control which changes form of said 1st field, and form of said 2nd field mutually-independent, and a polarization condition of light flux which passes through said 1st field and a polarization condition of light flux which passes through said 2nd field mutually-independent.
[Claim 2]
A division element for dividing light flux from said light source,
The 1st optical system for while having been divided and leading light flux to said 1st field on said illumination pupil plane via said division element,
The illumination optical device according to claim 1 provided with the 2nd optical system for leading light flux of another side divided via said division element to said 2nd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system.
[Claim 3]
The illumination optical device according to claim 2 having been arranged in an optical path between said light source and said division element, and having an illumination equalization means for equalizing illuminance distribution near said division element mostly.
[Claim 4]
The illumination optical device according to claim 2 or 3, wherein said division element carries out wavefront splitting of the light flux from said light source and leads it to said 1st optical system and said 2nd optical system.
[Claim 5]
The illumination optical device comprising according to claim 2 to 4:
The 1st light flux sensing element for changing into light flux corresponding to said 1st field light flux which said Lighting Sub-Division pupil means forming is arranged in an optical path of said 1st optical system, and enters.
The 2nd light flux sensing element for changing into light flux corresponding to said 2nd field light flux which is arranged in an optical path of said 2nd optical system, and enters.
An optical integrator for forming said Lighting Sub-Division pupil distribution in said illumination pupil plane based on light flux from said 1st light flux sensing element, and light flux from said 2nd light flux sensing element.

[Claim 6]
The illumination optical device comprising according to claim 2 to 5:
The 1st shape change means for said Lighting Sub-Division pupil control means being arranged in an optical path of said 1st optical system, and changing form of said 1st field.
The 2nd shape change means for being arranged in an optical path of said 2nd optical system, and changing form of said 2nd field.

[Claim 7]
Said 1st shape change means has the 1st axicon system arranged in an optical path between said 1st light flux sensing element and said optical integrator,
Said 2nd shape change means has the 2nd axicon system arranged in an optical path between said 2nd light flux sensing element and said optical integrator,
The illumination optical device according to claim 6, wherein it has the 2nd prism characterized by comprising the following, respectively and an interval of said 1st prism and said 2nd prism is constituted by variable.
The 1st prism with which said 1st axicon system and said 2nd axicon system have a refracting interface of a concave section.
A refracting interface of said concave section of this 1st prism, and a refracting interface of a convex section formed almost complementarily.

[Claim 8]
Said 1st shape change means has the 1st variable power optical system arranged in an optical path between said 1st light flux sensing element and said optical integrator,
The illumination optical device according to claim 7, wherein said 2nd shape change means has the 2nd variable power optical system arranged in an optical path between said 2nd light flux sensing element and said optical integrator.
[Claim 9]
An illumination optical device given in any 1 clause of Claims 2-8 characterized by comprising the following.
The 1st polarization condition alteration means for changing a polarization condition of light flux which said Lighting Sub-Division pupil control means is arranged in an optical path of said 1st optical system, and passes through said 1st field.
The 2nd polarization condition alteration means for changing a polarization condition of light flux which is arranged in an optical

path of said 2nd optical system, and passes through said 2nd field.

[Claim 10]
It has a primacy phase component for changing a polarization direction of linear polarization which said 1st polarization condition alteration means is arranged in an optical path of said 1st optical system, and enters if needed,
The illumination optical device according to claim 9 having the 2nd phase-parts material for changing a polarization direction of linear polarization which said 2nd polarization condition alteration means is arranged in an optical path of said 2nd optical system, and enters if needed.
[Claim 11]
Said 1st polarization condition alteration means is constituted to an optical path of said 1st optical system, enabling free insertion and detachment, and it has the 1st depolarization element for unpolarized-light-izing entering light if needed,
The illumination optical device according to claim 9 or 10 constituting said 2nd polarization condition alteration means to an optical path of said 2nd optical system, enabling free insertion and detachment, and having the 2nd depolarization element for unpolarized-light-izing entering light if needed.
[Claim 12]
Said Lighting Sub-Division pupil means forming is provided with the 2nd light flux sensing element for changing into light flux corresponding to said 2nd field light flux which is arranged in the 1st light flux sensing element for changing into light flux corresponding to said 1st field light flux which is arranged in an optical path of said 1st optical system, and enters, and an optical path of said 2nd optical system, and enters,
A primacy phase component for changing a polarization direction of linear polarization which said 1st polarization condition alteration means is arranged in an optical path between said division element and said 1st light flux sensing element, and enters if needed, It has the 1st depolarization element for unpolarized-light-izing light which is arranged enabling free insertion and detachment and enters into said optical path between said division element and said 1st light flux sensing element if needed,
The 2nd phase-parts material for changing a polarization direction of linear polarization which said 2nd polarization condition alteration means is arranged in an optical path between said division element and said 2nd light flux sensing element, and enters if needed, The illumination optical device according to claim 9 to 11 provided with the 2nd depolarization element for unpolarized-light-izing light which is arranged enabling free insertion and detachment and enters into said optical path between said division element and said 1st light flux sensing element if needed.
[Claim 13]
An illumination optical device given in any 1 clause of Claims 2-12, wherein said Lighting Sub-Division pupil control means has the 1st light intensity alteration means for changing light intensity of light flux which passes through said 1st field, and the 2nd light intensity alteration means for changing light intensity of light flux which passes through said 2nd field.
[Claim 14]
The illumination optical device according to claim 13, wherein said 1st light intensity alteration means is arranged in an optical path of said 1st optical system and said 2nd light intensity alteration means is arranged in an optical path of said 2nd optical system.
[Claim 15]
Said 1st light intensity alteration means has selectively at least one dimming means which can be inserted and detached freely to an optical path of said 1st optical system, The illumination optical device according to claim 14, wherein said 2nd light intensity alteration means has selectively at least one dimming means which can be inserted and detached freely to an optical path of said 2nd optical system.
[Claim 16]
An illumination optical device given in any 1 clause of Claims 3-15, wherein said 1st light flux sensing element and said 2nd light flux sensing element are constituted exchangeable to an optical path, respectively.
[Claim 17]
An illumination optical device given in any 1 clause of Claims 1-16, wherein said 1st field is a field which includes an optic axis on said illumination pupil plane and said 2nd field is a field distant from said optic axis on said illumination pupil plane.
[Claim 18]
The illumination optical device according to claim 17, wherein said 2nd field has the shape of zona orbicularis, or the shape of plural poles.
[Claim 19]
An illumination optical device given in any 1 clause of Claims 3-18 having further a light guide optical system for leading light flux from said optical integrator to said irradiated plane.
[Claim 20]
In an illumination optical device which illuminates an irradiated plane by light flux from a light source,
It has the Lighting Sub-Division pupil means forming for forming the Lighting Sub-Division pupil distribution which has light intensity distribution located in the 1st field on an illumination pupil plane, and the light intensity distribution located in the 2nd field,
Said Lighting Sub-Division pupil means forming,
A division element arranged in an optical path between said light source and said illumination pupil plane,
The 1st optical system for while having been divided and leading light flux to the 1st field on said illumination pupil plane via said division element,
The 2nd optical system for leading light flux of another side divided via said division element to the 2nd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system,
It is arranged in an optical path between said division element and said illumination pupil plane, and has a composite element for compounding an optic axis of said 1st optical system, and an optic axis of said 2nd optical system,
Said 1st optical system is provided with the 1st light flux sensing element for changing entering light flux into light flux corresponding to said 1st field,
An illumination optical device, wherein said 2nd optical system is provided with the 2nd light flux sensing element for changing entering light flux into light flux corresponding to said 2nd field.
[Claim 21]
An illumination optical device given in any 1 clause of Claims 2-20, wherein said Lighting Sub-Division pupil means forming is

further provided with the 3rd optical system for leading light flux divided via said division element to the 3rd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system and said 2nd optical system.
[Claim 22]
An exposure device equipping any 1 clause of Claims 1-21 for illuminating a mask with an illumination optical device of a description, and exposing a pattern of said mask on a photosensitive substrate.
[Claim 23]
It has further a projection optical system for forming an image of a pattern of said mask on said photosensitive substrate,
The exposure device according to claim 22, wherein a pupil surface of said illumination optical device is mostly positioned by conjugate with a pupil posion of said projection optical system.
[Claim 24]
The Lighting Sub-Division process of illuminating a mask using an illumination optical device of a description in any 1 clause of Claims 1-21,
An exposure method including an exposure process which exposes a pattern of said mask on a photosensitive substrate.
[Claim 25]
Said exposure process includes a projection process of forming an image of a pattern of said mask on said photosensitive substrate using a projection optical system,
The exposure method according to claim 24, wherein a pupil surface of said illumination optical device is mostly positioned by conjugate with a pupil posion of said projection optical system.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
Especially this invention relates to the suitable illumination optical device for the exposure device for manufacturing micro devices, such as a semiconductor device, an image sensor, a liquid crystal display element, and a thin film magnetic head, by a lithography step about an illumination optical device, an exposure device, and an exposure method.
[Background of the Invention]
[0002]
In this kind of typical exposure device, the light flux ejected from the light source via the fly eye lens (or micro fly eye lens) as an optical integrator, The secondary light source (predetermined light intensity distribution generally formed in an illumination pupil plane) as the substantial surface light source which consists of many light sources is formed. The light flux from a secondary light source enters into a condenser lens, after being restricted via the aperture diaphragm arranged near the backside focal plane of a fly eye lens.
[0003]
The light flux condensed with the condenser lens illuminates in superposition the mask in which the predetermined pattern was formed. Image formation of the light which penetrated the pattern of the mask is carried out on a wafer via a projection optical system. In this way, on a wafer, projection exposure (transfer) of the mask pattern is carried out. The pattern formed in the mask is integrated highly and it is indispensable to transfer this minute pattern correctly on a wafer to acquire uniform illuminance distribution on a wafer.
[0004]
Then, the secondary light source of a circle configuration is formed in the backside focal plane of a fly eye lens, and the technology of changing the size and changing the coherency sigma of Lighting Sub-Division (sigma value = the pupil diameter of the diameter of an aperture diaphragm / projection optical system or the incidence side numerical aperture of the number of injection side openings / projection optical system of a sigma value = illumination-light study system) attracts attention. The secondary light source of the shape of zona orbicularis or the shape of 4 poles is formed in the backside focal plane of a fly eye lens, and the technology of raising the depth of focus and resolution of a projection optical system attracts attention.
[Description of the Invention]
[Problem to be solved by the invention]
[0005]
In the above conventional exposure devices, according to the pattern characteristic of a mask, usual circular Lighting Sub-Division based on the secondary light source of a circle configuration is performed, or deformation illumination (4 very zona-orbicularis Lighting Sub-Division and Lighting Sub-Division) based on the secondary light source of the shape of zona orbicularis or the shape of 4 poles is performed. However, the Lighting Sub-Division conditions which were rich in diversity about the form and light intensity of relevant Lighting Sub-Division conditions required in order to transfer faithfully the mask pattern which has various characteristics, for example, a secondary light source, a polarization condition, etc. were not able to be realized.
[0006]
This invention is made in view of above-mentioned SUBJECT, and is a thing.
the purpose is to provide the illumination optical device which can realize the Lighting Sub-Division conditions which were rich in diversity about the form and light intensity of relevant Lighting Sub-Division conditions required in order to transfer faithfully the mask pattern which has various characteristics, for example, a secondary light source, a polarization condition, etc., when it is alike and is carried.

[0007]
An illumination optical device which can realize relevant Lighting Sub-Division conditions required in order that this invention may transfer faithfully a mask pattern which has various characteristics, for example is used, It aims at providing an exposure device and an exposure method which can perform good exposure under relevant Lighting Sub-Division conditions realized according to the pattern characteristic of a mask.
[Means for solving problem]
[0008]
In an illumination optical device which illuminates an irradiated plane according to light flux from a light source in the 1st form of this invention in order to solve said SUBJECT,
The Lighting Sub-Division pupil means forming for forming the Lighting Sub-Division pupil distribution which has light intensity distribution located in the 1st field on an illumination pupil plane, and the light intensity distribution located in the 2nd field, Control which changes form of said 1st field, and form of said 2nd field mutually-independent, An illumination optical device provided with the Lighting Sub-Division pupil control means for performing control which changes a polarization condition of light flux which passes through said 1st field, and a polarization condition of light flux which passes through said 2nd field mutually-independent is provided.
[0009]
A division element for dividing light flux from said light source according to the desirable mode of the 1st form, It has the 2nd

optical system for leading light flux of another side which while was divided via said division element and divided via the 1st optical system and said division element for leading light flux to said 1st field on said illumination pupil plane to said 2nd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system. In this case, it is preferred for it to have been arranged in an optical path between said light source and said division element, and to have an illumination equalization means for equalizing illuminance distribution near said division element mostly. As for said division element, it is preferred to carry out wavefront splitting of the light flux from said light source, and to lead to said 1st optical system and said 2nd optical system.

[0010]

According to the desirable mode of the 1st form, said Lighting Sub-Division pupil means forming is provided with the following.

The 1st light flux sensing element for changing into the light flux corresponding to said 1st field the light flux which is arranged in the optical path of said 1st optical system, and enters.

The 2nd light flux sensing element for changing into the light flux corresponding to said 2nd field the light flux which is arranged in the optical path of said 2nd optical system, and enters.

The optical integrator for forming said Lighting Sub-Division pupil distribution in said illumination pupil plane based on the light flux from said 1st light flux sensing element, and the light flux from said 2nd light flux sensing element.

As for said Lighting Sub-Division pupil control means, it is preferred to have the 1st shape change means for being arranged in the optical path of said 1st optical system, and changing the form of said 1st field and the 2nd shape change means for being arranged in the optical path of said 2nd optical system, and changing the form of said 2nd field.

[0011]

According to the desirable mode of the 1st form, said 1st shape change means, Have the 1st axicon system arranged in the optical path between said 1st light flux sensing element and said optical integrator, and said 2nd shape change means, Have the 2nd axicon system arranged in the optical path between said 2nd light flux sensing element and said optical integrator, and said 1st axicon system and said 2nd axicon system, It has the 1st prism that has a refracting interface of a concave section, and the 2nd prism that has a refracting interface of said concave section of this 1st prism, and a refracting interface of the convex section formed almost complementarily, respectively, and the interval of said 1st prism and said 2nd prism is constituted by variable. In this case, have said 1st shape change means and the 1st variable power optical system arranged in the optical path between said 1st light flux sensing element and said optical integrator said 2nd shape change means, It is preferred to have the 2nd variable power optical system arranged in the optical path between said 2nd light flux sensing element and said optical integrator.

[0012]

According to the desirable mode of the 1st form, said Lighting Sub-Division pupil control means is provided with the following.

The 1st polarization condition alteration means for changing the polarization condition of the light flux which is arranged in the optical path of said 1st optical system, and passes through said 1st field.

The 2nd polarization condition alteration means for changing the polarization condition of the light flux which is arranged in the optical path of said 2nd optical system, and passes through said 2nd field.

In this case, it has a primacy phase component for changing the polarization direction of the linear polarization which said 1st polarization condition alteration means is arranged in the optical path of said 1st optical system, and enters if needed, As for said 2nd polarization condition alteration means, it is preferred to have the 2nd phase-parts material for changing the polarization direction of the linear polarization which is arranged in the optical path of said 2nd optical system, and enters if needed. Said 1st polarization condition alteration means is constituted to the optical path of said 1st optical system, enabling free insertion and detachment, It has the 1st depolarization element for unpolarized-light-izing entering light if needed, and, as for said 2nd polarization condition alteration means, it is preferred for it to be constituted to the optical path of said 2nd optical system, enabling free insertion and detachment, and to have the 2nd depolarization element for unpolarized-light-izing entering light if needed.

[0013]

According to the desirable mode of the 1st form, said Lighting Sub-Division pupil means forming is provided with the following.

The 1st light flux sensing element for changing into the light flux corresponding to said 1st field the light flux which is arranged in the optical path of said 1st optical system, and enters.

Have the 2nd light flux sensing element for changing into the light flux corresponding to said 2nd field the light flux which is arranged in the optical path of said 2nd optical system, and enters, and said 1st polarization condition alteration means, The primacy phase component for changing the polarization direction of the linear polarization which is arranged in the optical path between said division element and said 1st light flux sensing element, and enters if needed.

It has the 1st depolarization element for unpolarized-light-izing light which is arranged enabling free insertion and detachment and enters into said optical path between said division element and said 1st light flux sensing element if needed, The 2nd phase-parts material for changing the polarization direction of the linear polarization which said 2nd polarization condition alteration means is arranged in the optical path between said division element and said 2nd light flux sensing element, and enters if needed.

The 2nd depolarization element for unpolarized-light-izing light which is arranged enabling free insertion and detachment and enters into said optical path between said division element and said 1st light flux sensing element if needed.

[0014]

According to the desirable mode of the 1st form, said Lighting Sub-Division pupil control means is provided with the following.

The 1st light intensity alteration means for changing the light intensity of the light flux which passes through said 1st field.

The 2nd light intensity alteration means for changing the light intensity of the light flux which passes through said 2nd field.

In this case, said 1st light intensity alteration means is arranged in the optical path of said 1st optical system, and, as for said 2nd light intensity alteration means, it is preferred to be arranged in the optical path of said 2nd optical system. Said 1st light intensity alteration means has selectively at least one dimming means which can be inserted and detached freely to the optical path of said 1st optical system in this case, and, as for said 2nd light intensity alteration means, it is preferred to have selectively at least one dimming means which can be inserted and detached freely to the optical path of said 2nd optical system.

[0015]

According to the desirable mode of the 1st form, said 1st light flux sensing element and said 2nd light flux sensing element are constituted exchangeable to the optical path, respectively. Said 1st field is a field which includes an optic axis on said illumination pupil plane, and, as for said 2nd field, it is preferred that it is the field distant from said optic axis on said illumination pupil plane.

In this case, as for said 2nd field, it is preferred to have the shape of zona orbicularis or the shape of plural poles. It is preferred to have further the light guide optical system for leading the light flux from said optical integrator to said irradiated plane.
[0016]
In the illumination optical device which illuminates an irradiated plane according to the light flux from a light source in the 2nd form of this invention,
It has the Lighting Sub-Division pupil means forming for forming the Lighting Sub-Division pupil distribution which has the light intensity distribution located in the 1st field on an illumination pupil plane, and the light intensity distribution located in the 2nd field,
Said Lighting Sub-Division pupil means forming,
The division element arranged in the optical path between said light source and said illumination pupil plane,
The 1st optical system for while having been divided and leading light flux to the 1st field on said illumination pupil plane via said division element,
The 2nd optical system for leading the light flux of another side divided via said division element to the 2nd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system,
It is arranged in the optical path between said division element and said illumination pupil plane, and has a composite element for compounding the optic axis of said 1st optical system, and the optic axis of said 2nd optical system,
Said 1st optical system is provided with the 1st light flux sensing element for changing the entering light flux into the light flux corresponding to said 1st field,
An illumination optical device, wherein said 2nd optical system is provided with the 2nd light flux sensing element for changing the entering light flux into the light flux corresponding to said 2nd field is provided.
[0017]
According to the desirable mode of the 2nd form, said Lighting Sub-Division pupil means forming is further provided with the 3rd optical system for leading the light flux divided via said division element to the 3rd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system and said 2nd optical system.
[0018]
In the 3rd form of this invention, it has an illumination optical device of the 1st form for illuminating a mask, or the 2nd form, and the exposure device exposing the pattern of said mask on a photosensitive substrate is provided. In this case, it has further a projection optical system for forming the image of the pattern of said mask on said photosensitive substrate, and, as for the pupil surface of said illumination optical device, it is preferred to be mostly positioned by conjugate with the pupil posion of said projection optical system.
[0019]
In the 4th form of this invention, an exposure method including the Lighting Sub-Division process of illuminating a mask using the illumination optical device of the 1st form or the 2nd form, and the exposure process which exposes the pattern of said mask on a photosensitive substrate is provided. In this case, it is preferred that the pupil surface of said illumination optical device is mostly positioned by conjugate with the pupil posion of said projection optical system including the projection process at which said exposure process forms the image of the pattern of said mask on said photosensitive substrate using a projection optical system.
[Effect of the Invention]
[0020]
In the illumination optical device of this invention, for example by operation of a light flux sensing element like a diffraction optical element, an optical integrator like a micro fly eye lens, etc. The secondary light source of the Lighting Sub-Division pupil distribution which has the light intensity distribution located in the 1st field on an illumination pupil plane and the light intensity distribution located in the 2nd field, the shape of for example, 5 poles, is formed. And an operation of an axicon system, a variable power optical system, etc. performs control which changes the form of the 1st field, and the form of the 2nd field mutually-independent, for example. For example, an operation of phase-parts material, a depolarizer (depolarization element), etc. like 1/2 wavelength plate performs control which changes the polarization condition of the light flux which passes through the 1st field, and the polarization condition of the light flux which passes through the 2nd field mutually-independent.
[0021]
Therefore, when the illumination optical device of this invention is carried, for example in an exposure device, the Lighting Sub-Division conditions which were rich in diversity about the form and light intensity of relevant Lighting Sub-Division conditions required in order to transfer faithfully the mask pattern which has various characteristics, for example, a secondary light source, a polarization condition, etc. can be realized. In the exposure device and exposure method using an illumination optical device of this invention. Since relevant Lighting Sub-Division conditions required in order to transfer faithfully the mask pattern which has various characteristics are realizable, Good exposure can be performed under the relevant Lighting Sub-Division conditions realized according to the pattern characteristic of a mask, and a good device can be manufactured by a high throughput by extension.
[Best Mode of Carrying Out the Invention]
[0022]
The embodiment of this invention is described based on an accompanying drawing.
Drawing 1 is a figure showing roughly the entire configuration of the exposure device concerning the embodiment of this invention. Drawing 2 is a figure showing roughly the internal configuration of the control unit in drawing 1. In drawing 1, the X-axis is set up in the direction vertical to the space of drawing 1 along the normal line direction of the wafer W which is a photosensitive substrate, respectively in [to a direction parallel to the space of drawing 1 / in the Z-axis / / in the field of the wafer W] the field of the wafer W for a Y-axis.
[0023]
If drawing 1 is referred to, the exposure device of this embodiment is provided with the light source 1 for supplying exposing light (illumination light). As the light source 1, the source of ArF excimer laser light etc. which supply light with a KrF excimer laser light source which supplies light with a wavelength of 248 nm, for example, and a wavelength of 193 nm can be used. The almost parallel light flux ejected from the light source 1 along with + Z direction has a section of the rectangular shape prolonged long and slender in accordance with the direction of X, and enters into the beam expander 2 which consists of the lens 2a and 2b of a couple. In the space of drawing 1 (inside of a YZ plane), each lens 2a and 2b have negative refracting power and positive refracting power, respectively.

[0024]
Therefore, in the space of drawing 1, the light flux which entered into the beam expander 2 is expanded, and is orthopedically operated by the light flux which has a section of predetermined rectangular shape. After the almost parallel light flux through the beam expander 2 as a plastic surgery optical system is deflected in the direction of +Y by the mirror 3, it is led to the control unit 5. To the optic axis AX, the mirror 3 is constituted by the operation of the mirror actuator 4 so that tilting is possible. The mirror actuator 4 controls the tilt of the mirror 3 based on the signal from the detectors 19a and 19b mentioned later.
[0025]
Reference of drawing 2 will enter the light flux led to the control unit 5 of this embodiment in the fly eye lens 11 which consists of a positive lens element of a large number arranged in all directions and densely, for example. The light flux which entered into the fly eye lens 11 is divided in two dimensions by many lens elements, and forms many light sources in an after that side focal plane or its neighborhood. The light flux from a light source forms in the rear side focal position or its neighborhood many radiation fields which have almost uniform illuminance distribution, after [which was formed in the backside focal plane of the fly eye lens 11, or its neighborhood] being condensed via the condenser lens 12.
[0026]
In the rear side focal position of the condenser lens 12, or its neighborhood, the rectangular prism 13 as a division element is arranged. Therefore, it is reflected in - Z direction and the light flux which entered into the 1st reflector 13a among the light flux which entered into the rectangular prism 13 via the condenser lens 12 is led to the 1st optical system, it is reflected in + Z direction and the light flux which entered into the 2nd reflector 13b is led to the 2nd optical system. Although the 1st optical system and the 2nd optical system have the same composition fundamentally, only the characteristic of the diffraction optical element 20 mentioned later is mutually different.
[0027]
Then, in drawing 2, the mark "a" is attached to the element which constitutes the 1st optical system at a reference number, and the mark "b" is attached to the same reference number as the correspondence element which constitutes the 2nd optical system. Hereafter, on the occasion of the composition of the 1st optical system and the 2nd optical system, and explanation of an operation, the reference mark etc. with which the 2nd optical system corresponds are described in the parenthesis. The light flux led to the 1st optical system (the 2nd optical system) enters into the beam splitter 15a (15b) via the relay lens 14a (14b). The light flux of most which was reflected in the direction of +Y enters into the polarization condition changing part 17a (17b) via the relay lens 16a (16b) by the beam splitter 15a (15b).
[0028]
1/4 wavelength-plate 17aa (17ba) which the polarization condition changing part 17a (17b) comprised to the optical path sequentially from the light source side so that insertion and detachment were possible, It is constituted by 1/2 wavelength-plate 17ab (17bb) constituted to the optical path so that insertion and detachment were possible, and depolarizer (unpolarized light-ized element) 17ac (17bc) constituted to the optical path so that insertion and detachment were possible. The detailed composition and operation of the polarization condition changing part 17a (17b) are mentioned later.
[0029]
On the other hand, the light flux which penetrated the beam splitter 15a (15b) reaches the detector 19a (19b) via the relay lens 18a (18b). Here, the rear side focal position of the condenser lens 12 and the detecting face of the detector 19a (19b) are optically arranged mostly at conjugate via the relay lens 14a (14b) and the relay lens 18a (18b). In this way, the relay lens 18a (18b) and the detector 19a (19b) constitute the light volume detection system for detecting the light volume (light intensity) of the light flux led to the 1st optical system (the 2nd optical system), and detecting the light volume split ratio in the rectangular prism 13 by extension.
[0030]
The output signal of the detector 19a (19b) is supplied to the mirror actuator 4. Only a predetermined angle makes the mirror 3 tilt based on the signal from the detectors 19a and 19b, and the mirror actuator 4 makes optic-axis direction crossing at a right angle carry out parallel translation of the radiation field formed near the rectangular prism 13, as mentioned above (to Z direction). A paraphrase will change the ratio of the light volume (light intensity) of the light flux which the light volume split ratio in the rectangular prism 13 changes, and is led by extension to the 1st optical system by the tilt of the mirror 3 based on the instructions from the mirror actuator 4, and the light volume (light intensity) of the light flux led to the 2nd optical system.
[0031]
The light flux which passed the polarization condition changing part 17a (17b) enters into the afocal lens 21a (21b) via the diffraction optical element 20a (20b). Here, the reflector 13a (13b) and the diffraction optical element 20a (20b) of the rectangular prism 13 are optically arranged mostly at conjugate via the relay lens 14a (14b) and the relay lens 16a (16b). the afocal lens 21a (21b) -- the front side focal position and the position of the diffraction optical element 20a (20b) -- about -- it is the afocal system (non-focal optical system) set up so that the position of the predetermined side 22a (22b) which I do and is shown by the rear side focal position and a figure destructive line might be mostly in agreement one.
[0032]
Generally, a diffraction optical element is constituted by forming the level difference which has a pitch about the wavelength of exposing light (illumination light) in a substrate, and has the operation diffracted at the angle of a request of an incident beam. Specifically, the 1st diffraction optical element 20a arranged in the optical path of the 1st optical system has a function which forms the light intensity distribution of a circle configuration in the far field (or Fraunhofer diffraction field), when the parallel pencil which has a section of rectangular shape enters. On the other hand, the 2nd diffraction optical element 20b arranged in the optical path of the 2nd optical system has a function which forms 4 pole-like light intensity distribution in the far field (or Fraunhofer diffraction field), when the parallel pencil which has a section of rectangular shape enters.
[0033]
therefore, it entered into the diffraction optical element 20a (20b) as a light flux sensing element -- a parallel pencil mostly, After forming the light intensity distribution of a circle configuration (the shape of 4 poles) in the pupil surface of the afocal lens 21a (21b), or its neighborhood, it becomes a parallel pencil mostly and is ejected from the afocal lens 21a (21b). Although the cone axicon system 23a (23b) is arranged in the pupil surface or its neighborhood in the optical path between front side lens group 21aa (21ba) of the afocal lens 21a (21b), and back side lens group 21ab (21bb), The detailed composition and operation are mentioned later.
[0034]
Hereafter, in order to simplify explanation, an operation of the cone axicon system 23a (23b) is disregarded, and fundamental

composition and operation are explained. The light flux through the afocal lens 21a (21b) is ejected from the 1st optical system (the 2nd optical system) via the zoom lens 24a (24b) and the relay lens 25a (25b) for sigma value variable. The light flux ejected from the 1st optical system and the 2nd optical system, respectively enters into the micro fly eye lens (or fly eye lens) 6 as an optical integrator via the condensing optical system 26.

[0035]

In the control unit 5, the entrance plane of the fly eye lens 11, The reflector 13a (13b) of the rectangular prism 13, the detecting face of the detector 19a (19b), the diffraction optical element 20a (20b), the predetermined side 22a (22b), and the backside focal plane (or front side focal plane of the condensing optical system 26) of the relay lens 25a (25b) have conjugate mostly optically. The backside focal plane (or projection surface) of the fly eye lens 11 and the beam splitter 15a (15b), The cone axicon system 23a (23b) and the backside focal plane (or front side focal plane of the relay lens 25a (25b)) of the zoom lens 24a (24b) have conjugate mostly optically.

[0036]

The micro fly eye lens 6 is an optical element which consists of a microlens which has the positive refractive power of a large number arranged in all directions and densely, for example. Generally, a micro fly eye lens is constituted by performing an etching process, for example to a plane-parallel plate, and forming a microlens group. Here, each microlens which constitutes a micro fly eye lens is minuter than each lens element which constitutes a fly eye lens. Unlike the fly eye lens which consists of a lens element isolated mutually, the micro fly eye lens is formed in one, without isolating many microlenses (minute refracting interface) mutually.

[0037]

However, a micro fly eye lens is the same wavefront-splitting type optical integrator as a fly eye lens at the point that the lens element which has positive refractive power is arranged in all directions. in addition -- the position of the predetermined side 22a (22b) is arranged in the front side focal position of the zoom lens 24a (24b), or its neighborhood -- the rear side focal position of the zoom lens 24a (24b), and the front side focal position of the relay lens 25a (25b) -- about -- I am doing one. The rear side focal position of the relay lens 25a (25b) is arranged in the front side focal plane of the condensing optical system 26, or its neighborhood, and the entrance plane of the micro fly eye lens 6 is arranged in the rear side focal position of the condensing optical system 26, or its neighborhood.

[0038]

When it puts in another way, the zoom lens 24a (24b), the relay lens 25a (25b), and the condensing optical system 26, The predetermined side 22a (22b) and the entrance plane of the micro fly eye lens 6 have been substantially arranged in the relation of the Fourier transform, and the pupil surface of the afocal lens 21a (21b) and the entrance plane of the micro fly eye lens 6 are optically arranged mostly to conjugate by extension. Therefore, on the entrance plane of the micro fly eye lens 6. The radiation field of the shape of 5 poles which consists of composition with the light intensity distribution of the circle configuration formed in the pupil surface of the 1st afocal lens 21a in the 1st optical system or its neighborhood and the light intensity distribution of the shape of 4 poles formed in the pupil surface of the 2nd afocal lens 21b in the 2nd optical system or its neighborhood is formed. The whole shape of the radiation field of the shape of these 5 poles changes in similarity depending on the focal distance of the zoom lens 24a (24b).

[0039]

Each microlens which constitutes the micro fly eye lens 6 has a section of rectangular shape [**** / the form (as a result, form of the exposure region which should be formed on the wafer W) of the radiation field which should be formed on the mask M]. The light flux which entered into the micro fly eye lens 6 is divided in two dimensions by many microlenses, The secondary light source which has the almost same light intensity distribution as the radiation field formed in an after that side focal plane or its neighborhood at the entrance plane of the micro fly eye lens 6 (to as a result, illumination pupil plane), That is, the secondary light source 40 of the shape of 5 poles which consists of the substantial surface light source 40a of the circle configuration centering on the optic axis AX and the four substantial circular surface light sources 40b1 to 40b4 symmetrically arranged, for example about the optic axis AX as shown in drawing 3 is formed.

[0040]

The light flux from the secondary light source (the Lighting Sub-Division pupil distribution) of the shape of 5 poles formed in the backside focal plane of the micro fly eye lens 6 or its neighborhood illuminates the mask blinds 9 in superposition, after passing the beam splitter 7a and the condenser optical systems 8. In this way, the radiation field of the rectangular shape according to the form and the focal distance of each microlens which constitute the micro fly eye lens 6 is formed in the mask blinds 9 as a lighting field diaphragm. The internal configuration of the polarization monitor 7 and operation which build in the beam splitter 7a are mentioned later. The light flux through the opening (light transmission section) of the rectangular shape of the mask blinds 9 illuminates in superposition the mask M in which the predetermined pattern was formed, after receiving a condensing operation of the image formation optical system 10.

[0041]

That is, the image formation optical system 10 will form the image of the rectangular shape opening of the mask blinds 9 on the mask M. The light flux which penetrated the pattern of the mask M held by mask stage MS forms the image of a mask pattern on the wafer (photosensitive substrate) W held by wafer stage WS via projection optical system PL. Here, the backside focal plane of the micro fly eye lens 6 or the illumination pupil plane of the neighborhood is mostly positioned by conjugate with the pupil posion of projection optical system PL. In this way, the pattern of the mask M is exposed one by one by each exposure region of the wafer W by performing one-shot exposure or scan exposure, carrying out drive controlling of the wafer W in two dimensions into the flat surface (XY plane) which intersects perpendicularly with the optic axis AX of projection optical system PL.

[0042]

In the polarization condition changing part 17a (17b), a crystal optics axis is constituted centering on the optic axis AX, enabling free rotation, and 1 / 4 wavelength-plate 17aa (17ba) changes the light of the entering elliptically polarized light into the light of linear polarization. A crystal optics axis is constituted centering on the optic axis AX, enabling free rotation, and 1 / 2 wavelength-plate 17ab (17bb) changes the plane of polarization of the entering linear polarization. Depolarizer 17ac (17bc) is constituted by the crystal prism of a wedge shape and the quartz prism of a wedge shape which have complementary form. It is constituted to the lighting optical path as an one prism assembly [crystal prism and quartz prism], enabling free insertion and detachment.

[0043]

When using a KrF excimer laser light source and the source of ArF excimer laser light as the light source 1, the light ejected from

these light sources has not less than 95% of polarization degree typically, and the light of linear polarization enters into 1 / 4 wavelength-plate 17aa (17ba) mostly. However, if the plane of polarization of the entering linear polarization is not in agreement with P plane of polarization or S plane of polarization when the rectangular prism as a rear reflection mirror intervenes in the optical path between the light source 1 and the polarization condition changing part 17a (17b), linear polarization will change to elliptically polarized light by the total internal reflection in a rectangular prism.

[0044]

In the polarization condition changing part 17a (17b), even if it originates, for example in the total internal reflection in a rectangular prism and the light of elliptically polarized light enters, the light of the linear polarization changed by operation of 1 / 4 wavelength-plate 17aa (17ba) enters into 1 / 2 wavelength-plate 17ab (17bb). When set up make the angle of 0 times or 90 degrees to the plane of polarization of linear polarization into which the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb) enters, the light of the linear polarization which entered into 1 / 2 wavelength-plate 17ab (17bb) passes as it is, without a plane of polarization changing.

[0045]

When set up make the angle of 45 degrees to the plane of polarization of linear polarization into which the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb) enters, the light of the linear polarization which entered into 1 / 2 wavelength-plate 17ab (17bb) is changed into the light of linear polarization from which the plane of polarization changed only 90 degrees. When set up make the angle of 45 degrees to the plane of polarization of linear polarization into which the crystal optics axis of the crystal prism of depolarizer 17ac (17bc) enters, the light of the linear polarization which entered into crystal prism is changed into the light of an unpolarized light state (unpolarized-light-izing).

[0046]

It comprises the polarization condition changing part 17a (17b) so that the angle of 45 degrees may be made to the plane of polarization of linear polarization into which the crystal optics axis of crystal prism enters, when depolarizer 17ac (17bc) is positioned in a lighting optical path. When set up make the angle of 0 times or 90 degrees incidentally to the plane of polarization of linear polarization into which the crystal optics axis of crystal prism enters, the light of the linear polarization which entered into crystal prism passes as it is, without a plane of polarization changing. When set up make the angle of 22.5 degrees to the plane of polarization of linear polarization into which the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb) enters, The light of the linear polarization which entered into 1 / 2 wavelength-plate 17ab (17bb) is changed into the light of an unpolarized light state containing the linearly polarized light component passed as it is and the linearly polarized light component from which the plane of polarization changed only 90 degrees, without a plane of polarization changing.

[0047]

In the polarization condition changing part 17a (17b), as mentioned above, the light of linear polarization enters into 1 / 2 wavelength-plate 17ab (17bb), but. In order to simplify the following explanation, the light of linear polarization ("Z direction polarization" is called hereafter) which has a polarization direction (the direction of an electric field) in a Z direction in drawing 2 shall enter into 1 / 2 wavelength-plate 17ab (17bb). If it sets up make the angle of 0 times or 90 degrees to the plane of polarization (polarization direction) of the Z direction polarization which enters the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb) when depolarizer 17ac (17bc) is positioned in a lighting optical path, Without a plane of polarization changing, the light of the Z direction polarization which entered into 1 / 2 wavelength-plate 17ab (17bb) passes with Z direction polarization, and enters into the crystal prism of depolarizer 17ac (17bc). Since the crystal optics axis of crystal prism is set up make the angle of 45 degrees to the plane of polarization of the entering Z direction polarization, the light of the Z direction polarization which entered into crystal prism is changed into the light of an unpolarized light state.

[0048]

The light unpolarized-light-ized via crystal prism enters into the diffraction optical element 20a (20b) in the state of unpolarized light via the quartz prism as a compensator for compensating the direction of movement of light. If it sets up make the angle of 45 degrees on the other hand to the plane of polarization of the Z direction polarization which enters the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb), A plane of polarization changes only 90 degrees, and the light of the Z direction polarization which entered into 1 / 2 wavelength-plate 17ab (17bb) turns into light of linear polarization ("the direction polarization of X" is called hereafter) which has a polarization direction (the direction of an electric field) in the direction of X in drawing 2, and enters into the crystal prism of depolarizer 17ac (17bc). Since the crystal optics axis of crystal prism is set up make the angle of 45 degrees also to the plane of polarization of the entering direction polarization of X, the light of the direction polarization of X which entered into crystal prism is changed into the light of an unpolarized light state, and enters into the diffraction optical element 20a (20b) in the state of unpolarized light via quartz prism.

[0049]

On the other hand, if it sets up make the angle of 0 times or 90 degrees to the plane of polarization of the Z direction polarization which enters the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb) when depolarizer 17ac (17bc) is evacuated from a lighting optical path, The light of the Z direction polarization which entered into 1 / 2 wavelength-plate 17ab (17bb) passes with Z direction polarization, without a plane of polarization changing, and enters into the diffraction optical element 20a (20b) by a Z direction polarization condition. If it sets up make the angle of 45 degrees on the other hand to the plane of polarization of the Z direction polarization which enters the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb), A plane of polarization changes only 90 degrees, and the light of the Z direction polarization which entered into 1 / 2 wavelength-plate 17ab (17bb) turns into light of the direction polarization of X, and enters into the diffraction optical element 20a (20b) by the direction polarization condition of X.

[0050]

As mentioned above, in the polarization condition changing part 17a (17b), the light of an unpolarized light state can be entered in the diffraction optical element 20a (20b) by inserting depolarizer 17ac (17bc) into a lighting optical path, and positioning it. By setting up make the angle of 0 times or 90 degrees to the plane of polarization of the Z direction polarization which evacuates depolarizer 17ac (17bc) from a lighting optical path, and enters the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb), The light of a Z direction polarization condition can be entered in the diffraction optical element 20a (20b). By setting up make 45 degrees to the plane of polarization of the Z direction polarization which evacuates depolarizer 17ac (17bc) from a lighting optical path, and enters the crystal optics axis of 1 / 2 wavelength-plate 17ab (17bb), The light of the direction polarization condition of X can be entered in the diffraction optical element 20a (20b).

[0051]

If it puts in another way, by operation of the polarization condition changing part 17a (17b) which consists of 1 / 4 wavelength-

plate 17aa (17ba), 1/2 wavelength-plate 17ab (17bb), and depolarizer 17ac (17bc). The polarization condition of the incident light to the diffraction optical element 20a (20b) as a result, the polarization condition of the light which passes the surface light source 40a (4 pole-like surface light source 40b1 to 40b4) of the circle configuration of the secondary light source 40, It can switch between a linear polarization state and an unpolarized light state, and when it is in a linear polarization state, it can switch between the polarization conditions which intersect perpendicularly mutually (between Z direction polarization and the direction polarization of X).

[0052]

Generally the polarization condition of the incident light to the diffraction optical element 20a (20b) can also be set as the linear polarization state of having a polarization direction in an arbitrary direction, by operation of 1 / 2 wavelength-plate 17ab (17bb). In the polarization condition changing part 17a (17b). Both 1 and / 2 wavelength-plate 17ab (17bb), and depolarizer 17ac (17bc) are evacuated from a lighting optical path, And the light of a circular light state can be entered in the diffraction optical element 20a (20b) by setting up make a predetermined angle to the elliptically polarized light which enters the crystal optics axis of 1 / 4 wavelength-plate 17aa (17ba).

[0053]

Next, the cone axicon system 23a (23b), 1st prism component 23aa (23ba) which turned the flat surface to the light source side (light incidence side), and turned the concave cone-like refracting interface to the mask side (irradiation appearance side) sequentially from the light source side, It comprises 2nd prism component 23ab (23bb) which turned the flat surface to the mask side, and turned the refracting interface of convex conical shape to the light source side. And the refracting interface of the shape of a concave cone of 1st prism component 23aa (23ba) and the refracting interface of the convex conical shape of 2nd prism component 23ab (23bb) are complementarily formed so that it can contact mutually. At least one component is constituted movable in accordance with the optic axis AX among 1st prism component 23aa (23ba) and 2nd prism component 23ab (23bb), The interval of the refracting interface of the shape of a concave cone of 1st prism component 23aa (23ba) and the refracting interface of the convex conical shape of 2nd prism component 23ab (23bb) is constituted by variable.

[0054]

Here in the state where the concave cone-like refracting interface of 1st prism component 23aa (23ba) and the convex conical shape refracting interface of 2nd prism component 23ab (23bb) have contacted mutually. The cone axicon system 23a (23b) does not have the influence which it has on the surface light source 40a (40b) of the circle configuration (the shape of 4 poles) which functions as a plane-parallel plate and constitutes the secondary light source 40 formed. However, if the concave cone-like refracting interface of 1st prism component 23aa (23ba) and the convex conical shape refracting interface of 2nd prism component 23ab (23bb) are made to estrange, the cone axicon system 23a (23b) will function as what is called a beam expander. Therefore, the angle of the incoming beam to the predetermined side 22a (22b) changes with change of the interval of the cone axicon system 23a (23b).

[0055]

Drawing 4 is a figure explaining an operation of a cone axicon system to the surface light source of the shape of 4 poles which constitutes a secondary light source. When drawing 4 is referred to, the interval of the cone axicon system 23b in the 2nd optical system by zero And the state where the focal distance of the zoom lens 24b was set as the minimum. The surface light source 41b1 to 41b4 of the shape of smallest 4 poles formed by (it is hereafter called a "normal condition") by making the interval of the cone axicon system 23b expand from zero to a predetermined value, It changes to the surface light source 42b1 to 42b4 of the shape of 4 poles to which the outer diameter and inside diameter were expanded [both], without the width (1/2 of the difference of the outer diameter which is a diameter of a circumscribed circle, and the inside diameter which is diameters of an inscribed circle: the both-directions arrow in a figure shows) changing. If it puts in another way, the zona-orbicularis ratio (inside diameter/outer diameter) and size (outer diameter) will change [both] with operations of the cone axicon system 23b, without the width of the 4 pole-like surface light source changing.

[0056]

On the other hand, although a graphic display is omitted, the surface light source of the shape of 4 poles formed by the normal condition of the zoom lens 24b changes to the surface light source of the shape of 4 poles to which the whole shape was expanded in similarity by making the focal distance of the zoom lens 24b expand from the minimum to a predetermined value. The width and size (outer diameter) change [both], without the whole 4 pole-like surface light source's 40b's1 to 40b's4 being expanded or reduced by variable power operation of the zoom lens 24b in similarity, and the zona-orbicularis ratio changing, if it puts in another way. Similarly, the surface light source 40a of a circle configuration is expanded or reduced by variable power operation of the zoom lens 24a in the 1st optical system in similarity. The zona-orbicularis ratio (inside diameter/outer diameter) and size (outer diameter) can also be changed [both], without changing the surface light source 40a of a circle configuration into the zona-orbicularis-like surface light source if needed, and changing the width (1/2 of the difference of an outer diameter and an inside diameter) by operation of the cone axicon system 23a in the 1st optical system.

[0057]

Drawing 5 is a figure explaining a collaboration operation with the cone axicon system and zoom lens to a secondary 5 pole-like light source. According to this embodiment, by variable power operation of the zoom lens 24a in the 1st optical system, as shown in drawing 5 (a), the surface light source of a circle configuration can be made comparatively small, or as shown in drawing 5 (b), the surface light source of a circle configuration can be enlarged comparatively. By collaboration operation with the cone axicon system 23b in the 2nd optical system, and the zoom lens 24b. Keeping a size (outer diameter) constant, as shown in drawing 5 (a), width of the 4 pole-like surface light source can be enlarged comparatively, or as shown in drawing 5 (b), width of the 4 pole-like surface light source can be made comparatively small.

[0058]

That is, generally the surface light source of a circle configuration can be independently expanded or reduced in similarity with the 4 pole-like surface light source by variable power operation of the zoom lens 24a in the 1st optical system, without being limited to the example shown in drawing 5. The surface light source of a circle configuration can change shape parameters, such as width of the 4 pole-like surface light source, a zona-orbicularis ratio (an inside diameter/outer diameter), and a size (outer diameter), independently by collaboration operation with the cone axicon system 23b in the 2nd optical system, and the zoom lens 24b. If needed, by collaboration operation with the cone axicon system 23a in the 1st optical system, and the zoom lens 24a, the surface light source of a circle configuration can be changed into the zona-orbicularis-like surface light source, and shape parameters, such as the width, a zona-orbicularis ratio (an inside diameter/outer diameter), and a size (outer diameter), can be changed.

[0059]
Drawing 6 is a perspective view showing the internal configuration of a polarization monitor of drawing 1 roughly. If drawing 6 is referred to, the polarization monitor 7 is provided with the 1st beam splitter 7a arranged in the optical path between the micro fly eye lens 6 and the condenser optical systems 8. The 1st beam splitter 7a has a form of the plane-parallel plate (namely, base glass) of the non coat formed, for example with silica glass, and has a function which takes out the reflected light of a different polarization condition from the polarization condition of incident light from an optical path.
[0060]
The light taken out from the optical path by the 1st beam splitter 7a enters into the 2nd beam splitter 7b. The 2nd beam splitter 7b has a form of the plane-parallel plate of the non coat formed, for example with silica glass like the 1st beam splitter 7a, and has the function to generate the reflected light of a different polarization condition from the polarization condition of incident light. And it is set up so that P polarization over the 1st beam splitter 7a may turn into S polarization over the 2nd beam splitter 7b and S polarization over the 1st beam splitter 7a may turn into P polarization over the 2nd beam splitter 7b.
[0061]
The light which penetrated the 2nd beam splitter 7b is detected by the 1st light-intensity detector 7c, and the light reflected by the 2nd beam splitter 7b is detected by the 2nd light-intensity detector 7d. The output of the 1st light-intensity detector 7c and the 2nd light-intensity detector 7d is supplied to a control section (un-illustrating), respectively. A control section drives 1 / 4 wavelength-plate 17aa (17ba), 1/2 wavelength-plate 17ab (17bb), and depolarizer 17ac (17bc) which constitute the polarization condition changing part 17a (17b) if needed.
[0062]
As mentioned above, in the 1st beam splitter 7a and the 2nd beam splitter 7b, the reflectance to P polarization differs from the reflectance to S polarization substantially. Therefore, in the polarization monitor 7 the reflected light from the 1st beam splitter 7a, For example, about 10% of S polarization component (P polarization component [as opposed to / are S polarization component to the 1st beam splitter 7a, and / the 2nd beam splitter 7b]) of the incident light to the 1st beam splitter 7a, For example, about 1% of P polarization component (S polarization component [as opposed to / are P polarization component to the 1st beam splitter 7a, and / the 2nd beam splitter 7b]) of the incident light to the 1st beam splitter 7a will be included.
[0063]
The reflected light from the 2nd beam splitter 7b, For example, 1% [10% x] = about 0.1% of P polarization component (S polarization component [as opposed to / are P polarization component to the 1st beam splitter 7a, and / the 2nd beam splitter 7b]) of the incident light to the 1st beam splitter 7a, For example, 10% [1% x] = about 0.1% of S polarization component (P polarization component [as opposed to / are S polarization component to the 1st beam splitter 7a, and / the 2nd beam splitter 7b]) of the incident light to the 1st beam splitter 7a will be included.
[0064]
In this way, in the polarization monitor 7, the 1st beam splitter 7a has a function which takes out the reflected light of a different polarization condition from the polarization condition of incident light from an optical path according to the reflection property. As a result, although slightly influenced by the polarization change by the polarization characteristic of the 2nd beam splitter 7b, the output (the information about the intensity of the transmitted light of the 2nd beam splitter 7b.) of the 1st light-intensity detector 7c namely, -- being based on the information about the luminous intensity of the almost same polarization condition as the reflected light from the 1st beam splitter 7a -- the polarization condition (polarization degree) of the incident light to the 1st beam splitter 7a -- as a result, the polarization condition of the illumination light to the mask M and the wafer W is detectable.
[0065]
In the polarization monitor 7, it is set up so that P polarization over the 1st beam splitter 7a may turn into S polarization over the 2nd beam splitter 7b and S polarization over the 1st beam splitter 7a may turn into P polarization over the 2nd beam splitter 7b. As a result, based on the output (information about the luminous intensity reflected one by one by the 1st beam splitter 7a and the 2nd beam splitter 7b) of the 2nd light-intensity detector 7d, without it receives substantially the influence of change of the polarization condition of the incident light to the 1st beam splitter 7a -- the light volume (intensity) of the incident light to the 1st beam splitter 7a -- as a result, the light volume of the illumination light to the mask M is detectable.
[0066]
In this way, it can be judged whether using the polarization monitor 7, the polarization condition of the incident light to the 1st beam splitter 7a is detected, and the illumination light to the mask M is in a desired unpolarized light state, linear polarization state, or circular light state by extension. A control section based on the detection result of the polarization monitor 7 And the unpolarized light state of a request of the illumination light to the mask M (as a result, the wafer W), When it is checked that it is not in a linear polarization state or a circular light state, 1/4 wavelength-plate 17aa which constitutes the polarization condition changing part 17a (17b) (17ba), Drive control of 1 / 2 wavelength-plate 17ab (17bb), and the depolarizer 17ac (17bc) can be carried out, and the state of the illumination light to the mask M can be adjusted to a desired unpolarized light state, linear polarization state, or circular light state.
[0067]
As mentioned above, the rectangular prism 13 constitutes the division element for carrying out wavefront splitting of the light flux from the light source 1, and leading to the 1st optical system (14a-25a) and the 2nd optical system (14b-25b) from this embodiment. In the optical path between the light source 1 and the rectangular prism 13, The fly eye lens 11 and the condenser lens 12 are arranged as an illumination equalization means for equalizing mostly the illuminance distribution of the means (the rectangular prism 13 near [i.e.,]) for forming the almost uniform radiation field of illuminance distribution near the rectangular prism 13.
[0068]
In this way, the light flux which was being steadily divided by the rectangular prism 13, The surface light source (light intensity distribution located in the 1st field that includes the optic axis AX in an illumination pupil plane) 40a of the circle configuration of the secondary light source 40 is formed via the 1st optical system (14a-25a) and the micro fly eye lens 6 containing the diffraction optical element 20a. On the other hand, the light flux of another side divided by the rectangular prism 13, Via the 2nd optical system (14b-25b) and the micro fly eye lens 6 which contain the diffraction optical element 20b in accordance with a different optical path from the 1st optical system (14a-25a), The surface light source (light intensity distribution located in the 2nd field distant from the optic axis AX in the illumination pupil plane) 40b of the shape of 4 poles of the secondary light source 40 is formed.
[0069]

Here, the diffraction optical element 20a (20b) constitutes the 1st light flux sensing element (the 2nd light flux sensing element) for changing into the light flux corresponding to the surface light source 40a (surface light source 40b of the shape of 4 poles of the 2nd field) of the circle configuration of the 1st field the light flux which is arranged in the optical path of the 1st optical system (the 2nd optical system), and enters. Based on the light flux from the diffraction optical element 20a as the 1st light flux sensing element, and the light flux from the diffraction optical element 20b as the 2nd light flux sensing element, the micro fly eye lens 6, The optical integrator for forming the secondary light source (the Lighting Sub-Division pupil distribution) 40 in an after that side focal plane or its neighborhood (namely, illumination pupil plane) is constituted.
[0070]
The diffraction optical element 20a as the 1st light flux sensing element, the diffraction optical element 20b as the 2nd light flux sensing element, And the micro fly eye lens 6 as an optical integrator, The Lighting Sub-Division pupil means forming for forming the secondary light source (the Lighting Sub-Division pupil distribution) 40 which has the surface light source (namely, light intensity distribution located in the 1st field on an illumination pupil plane) 40a of a circle configuration and the 4 pole-like surface light source (namely, light intensity distribution located in the 2nd field on an illumination pupil plane) 40b is constituted. The condenser optical systems 8 and the image formation optical system 10 constitute the light guide optical system for leading the light flux from the micro fly eye lens 6 as an optical integrator to the mask M which is an irradiated plane.
[0071]
As mentioned above, the cone axicon system 23a and the zoom lens (variable power optical system) 24a as the 1st axicon system constitute the 1st shape change means for being arranged in the optical path of the 1st optical system (14a-25a), and changing the form of the surface light source (the 1st field) 40a of a circle configuration. Similarly, the cone axicon system 23b and the zoom lens (variable power optical system) 24b as the 2nd axicon system constitute the 2nd shape change means for being arranged in the optical path of the 2nd optical system (14b-25b), and changing the form of the 4 pole-like surface light source (the 2nd field) 40b.
[0072]
As mentioned above, in the polarization condition changing part 17a (17b), 1 / 2 wavelength-plate 17ab (17bb) constitutes the primacy phase component (the 2nd phase-parts material) for changing the polarization direction of the linear polarization which is arranged in the optical path of the 1st optical system (the 2nd optical system), and enters if needed. Depolarizer 17ac (17bc) is constituted to the optical path of the 1st optical system (the 2nd optical system), enabling free insertion and detachment, and constitutes the 1st depolarization element (the 2nd depolarization element) for unpolarized-light-izing entering light if needed.
[0073]
1 / 4 wavelength-plate 17aa (17ba) constitutes the phase-parts material for changing into the light of linear polarization the light of the elliptically polarized light which is arranged in the optical path of the 1st optical system (the 2nd optical system), and enters. In this way, the polarization condition changing part 17a constitutes the 1st polarization condition alteration means for changing the polarization condition of the light flux which is arranged in the optical path of the 1st optical system, and passes the surface light source 40a of the circle configuration of the 1st field. On the other hand, the polarization condition changing part 17b constitutes the 2nd polarization condition alteration means for changing the polarization condition of the light flux which is arranged in the optical path of the 2nd optical system, and passes the surface light source 40b of the shape of 4 poles of the 2nd field.
[0074]
As mentioned above, the mirror 3, the mirror actuator 4, the fly eye lens 11, the condenser lens 12, and the rectangular prism 13, The light volume split ratio in the rectangular prism 13 is changed, As a result, the light intensity ratio alteration means for changing a ratio with the light intensity (light volume) of the light flux which is led to the light intensity (light volume) and the 2nd optical system of light flux which are led to the 1st optical system and pass the surface light source 40a of the circle configuration of the 1st field, and passes the surface light source 40b of the shape of 4 poles of the 2nd field is constituted.
[0075]
By in this way, operation with a 1st shape change means to have the cone axicon system 23a and the zoom lens 24a in this embodiment, and a 2nd shape change means to have the cone axicon system 23b and the zoom lens 24b. Control which changes the form of the surface light source 40a of the circle configuration of the 1st field and the form of the 2nd field 4 pole-like surface light source 40b mutually-independent can be performed. By operation with the 1st polarization condition alteration means which has the polarization condition changing part 17a, and the 2nd polarization condition alteration means which has the polarization condition changing part 17b. Control which changes the polarization condition of the light flux which passes the surface light source 40a of the circle configuration of the 1st field, and the polarization condition of the light flux which passes the surface light source 40b of the shape of 4 poles of the 2nd field mutually-independent can be performed.
[0076]
If it puts in another way, the 1st shape change means, the 2nd shape change means, the 1st polarization condition alteration means, and the 2nd polarization condition alteration means, The Lighting Sub-Division pupil control means for performing control which changes the control which changes the form of the 1st field and the form of the 2nd field mutually-independent, and the polarization condition of the light flux which passes through the 1st field and the polarization condition of the light flux which passes through the 2nd field mutually-independent is constituted. By operation of the light intensity ratio alteration means which has the mirror 3, the mirror actuator 4, the fly eye lens 11, the condenser lens 12, and the rectangular prism 13 in this embodiment. Control which changes the ratio of the light intensity of the light flux which passes the surface light source 40a of the circle configuration of the 1st field, and the light intensity of the light flux which passes the surface light source 40b of the shape of 4 poles of the 2nd field can be performed.
[0077]
As mentioned above, in the illumination optical device (1-10) of this embodiment, the Lighting Sub-Division conditions which were rich in diversity about the form and light intensity of relevant Lighting Sub-Division conditions required in order to transfer faithfully the mask pattern which has various characteristics, for example, a secondary light source, a polarization condition, etc. are realizable. With the exposure device of this invention, since relevant Lighting Sub-Division conditions required in order to transfer faithfully the mask pattern which has various characteristics are realizable, good exposure can be performed under the relevant Lighting Sub-Division conditions realized according to the pattern characteristic of a mask.
[0078]
It comprises an above-mentioned embodiment exchangeable with other diffraction optical elements which the diffraction optical elements 20a and 20b are constituted to an optical path at so that insertion and detachment are possible, and differ in the

characteristic. four [therefore,] in the 2nd optical system -- replacing with the diffraction optical element 20b very for Lighting Sub-Division -- 2 [for example,] -- setting up the diffraction optical element very for Lighting Sub-Division (8 very for Lighting Sub-Division) into an optical path -- 3 -- it can illuminate very much (9 very). Modification zona-orbicularis Lighting Sub-Division can be performed by replacing with the diffraction optical element 20b for 4 pole Lighting Sub-Division in the 2nd optical system, for example, setting up the diffraction optical element for zona-orbicularis Lighting Sub-Division into an optical path.
[0079]
8 pole Lighting Sub-Division can be performed by replacing with the diffraction optical element 20a for circular Lighting Sub-Division in the 1st optical system, for example, setting up the diffraction optical element 20b for 4 pole Lighting Sub-Division into an optical path. Deformation illumination of various forms can be performed by similarly, replacing with the diffraction optical element 20a for circular Lighting Sub-Division in the 1st optical system, or the diffraction optical element 20b for 4 pole Lighting Sub-Division in the 2nd optical system, and setting up the diffraction optical element which has the suitable characteristic into an optical path. The diffraction optical element 20b for 4 pole Lighting Sub-Division is evacuated from an optical path, circular Lighting Sub-Division can be performed, or the diffraction optical element 20a for circular Lighting Sub-Division can be evacuated from an optical path, and 4 pole Lighting Sub-Division can also be performed.
[0080]
In the above-mentioned embodiment, the light flux of another side where light flux was led to the 1st optical system (14a-25a), and while it was divided by the rectangular prism 13 was divided by the rectangular prism 13 is led to the 2nd optical system (14b-25b). However, the composition which leads the light flux divided via the division element to the 3rd field on an illumination pupil plane via the 3rd optical system in accordance with a different optical path from the 1st optical system and the 2nd optical system is also possible, without being limited to this.
For example, according to the 1st optical system (14a-25a) in the 1st field on an illumination pupil plane, Form the surface light source 40a shown in drawing 3, and according to the 2nd optical system (14b-25b) in the 2nd field on an illumination pupil plane, As composition which forms the surface light source 40b1 shown in drawing 3, and 40b4, and forms the surface light source 40b2 shown in drawing 3, and 40b3 in the 3rd field on an illumination pupil plane according to the 3rd different optical system (un-illustrating) from these 1st optical systems and the 2nd optical system, The polarization condition of the light flux which reaches the surface light source 40a is set as unpolarized light, the direction polarization of X, or Z direction polarization, It is set as the linear polarization which has a plane of polarization in the tangential direction of the circle [polarization condition / of the surface light source 40b1 and the light flux which amounts to 40b4] centering on an optic axis, It can also be set as the linear polarization (linear polarization to which the polarization direction of the surface light source 40b1 and the light flux which amounts to 40b4 has a plane of polarization in the direction which intersects perpendicularly) which has a plane of polarization in the tangential direction of the circle [polarization condition / of the surface light source 40b2 and the light flux which amounts to 40b3] centering on an optic axis.
[0081]
Drawing 7 is a figure showing roughly the composition of the control unit concerning the 1st modification of this embodiment. The control unit 50 of the 1st modification has composition similar to the control unit 5 of the embodiment shown in drawing 2. However, in the 1st modification, only the composition between the zoom lenses 24a and 24b and the micro fly eye lens 6 is different from the embodiment of drawing 2. Hereafter, paying attention to a point of difference with the embodiment of drawing 2, composition and an operation of the control unit 50 of the 1st modification are explained.
[0082]
If drawing 7 is referred to, in the control unit 50 of the 1st modification, the light flux ejected from the 1st optical system (14a-24a) via the zoom lens 24a will be reflected in + Z direction by the rectangular prism (or bending mirror) 27 as a deviation component. The light flux reflected in + Z direction by the rectangular prism 27 enters into the rectangular prism (or bending mirror) 29 as a deviation component arranged on the optic axis of the 2nd optical system via the relay lens system 28. The light flux from the 1st optical system reflected in the direction of +Y by the rectangular prism 29 reaches the micro fly eye lens 6 via the relay lens system 30.
[0083]
On the other hand, the light flux ejected from the 2nd optical system (14b-24b) via the zoom lens 24b reaches the micro fly eye lens 6 via the relay lens system 30, without being interrupted by the rectangular prism 29. In the 1st modification, the cone axicon system 23a (23b), the reflector of the rectangular prism 27, the reflector of the rectangular prism 29, and the entrance plane of the micro fly eye lens 6 have conjugate mostly optically. The predetermined side 22a (22b), the pupil surface of the relay lens system 28, the pupil surface of the relay lens system 30, and the backside focal plane (or projection surface) of the micro fly eye lens 6 have conjugate mostly optically.
[0084]
And the rectangular prisms 27 and 29 are arranged in the optical path between the rectangular prism 13 which is a division element, and the mask M which is illumination pupil planes, and constitute the composite element for compounding the optic axis of the 1st optical system (14a-24a), and the optic axis of said 2nd optical system (14b-24b). The control which changes the form of the surface light source 40a of the circle configuration of the 1st field, and the form of the 2nd field 4 pole-like surface light source 40b mutually-independent like an above-mentioned embodiment also in the 1st modification, The control which changes the polarization condition of the light flux which passes the surface light source 40a of the circle configuration of the 1st field, and the polarization condition of the light flux which passes the surface light source 40b of the shape of 4 poles of the 2nd field mutually-independent, And control which changes the ratio of the light intensity of the light flux which passes the surface light source 40a of the circle configuration of the 1st field, and the light intensity of the light flux which passes the surface light source 40b of the shape of 4 poles of the 2nd field can be performed.
[0085]
Drawing 8 is a figure showing roughly the important section composition of the control unit concerning the 2nd modification of this embodiment. The control unit 51 of the 2nd modification has important section composition similar to the control unit 5 of an embodiment and the control unit 50 of the 1st modification which are shown in drawing 2. However, in the 2nd modification, the composition between the mirror 3 and the polarization condition changing parts 17a and 17b is different from the embodiment of drawing 2, and the 1st modification. Hereafter, paying attention to the embodiment of drawing 2, and a point of difference with the 1st modification, composition and an operation of the control unit 51 of the 2nd modification are explained.
[0086]
Reference of drawing 8 will enter in the beam splitter 31 the light flux reflected in the direction of +Y by the mirror 3 in the

control unit 51 of the 2nd modification. The light flux which was reflected in − Z direction by the beam splitter 31, and was led to the 1st optical system reaches the polarization condition changing part 17a via at least one dark filter 33a, after being reflected in the direction of +Y by the bending mirror 32. The light flux which penetrated the beam splitter 31 and was led to the 2nd optical system on the other hand reaches the polarization condition changing part 17b via at least one dark filter 33b. The composition on the backside (micro fly eye lens 6 side) is the same as the embodiment of drawing 2, or the 1st modification than the polarization condition changing parts 17a and 17b.

[0087]

Here, it is constituted exchangeable with other dark filters which the dark filter 33a and the dark filter 33b are constituted to an optical path at so that insertion and detachment are possible, and differ in the characteristic. That is, to the optical path of the 1st optical system, the dark filter 33a is at least one dimming means which can be inserted and detached freely selectively, and constitutes the 1st light intensity alteration means for changing the light intensity of the light flux which is arranged in the optical path of the 1st optical system, and passes the surface light source 40a of the circle configuration of the 1st field. To the optical path of the 2nd optical system, the dark filter 33b is at least one dimming means which can be inserted and detached freely selectively, and constitutes the 2nd light intensity alteration means for changing the light intensity of the light flux which is arranged in the optical path of the 2nd optical system, and passes the surface light source 40b of the shape of 4 poles of the 2nd field.

[0088]

Therefore, the mirror actuator 4 for making the mirror 3 tilt in the 2nd modification is unnecessary. And the light volume split ratio in the beam splitter 31 is set as 1:1, for example, By exchanging the dark filter 33a and the dark filter 33b for other dark filters which differ in the characteristic, or evacuating the dark filter 33a and the dark filter 33b from an optical path, Unlike the embodiment of drawing 2, or the 1st modification, control which changes the light intensity of the light flux which passes the surface light source 40a of the circle configuration of the 1st field, and the light intensity of the light flux which passes the surface light source 40b of the shape of 4 poles of the 2nd field mutually-independent can be performed.

[0089]

In each above-mentioned embodiment or each modification, it may change to the fly eye lens 11 as an illumination equalization means, and the diffraction optical element which forms almost uniform light intensity distribution in the far field (or Fraunhofer diffraction field) may be applied. Here, the far field (or Fraunhofer diffraction field) of this diffraction optical element will be relayed to the rear side focal position of the condenser lens 12 or its neighborhood as an illumination equalization means.

[0090]

In each above-mentioned embodiment or each modification, the optical system from the diffraction optical element 20a (20b) in the 1st optical system (14a-25a) and the 2nd optical system (14b-25b) to the zoom lens 24a (24b), For example, the optical system from the diffraction optical element 51 of the illumination optical device indicated by JP,2001-176766,A to the zoom lens 7, The optical system from the microlens array 4 of the illumination optical device indicated by JP,2001-85923,A to the zoom lens 7, The optical system from the diffraction optical element 4 indicated by JP,2002-231619,A to the zoom lens 7, It is also possible to transpose to the optical system from the diffraction optical element 4 of the illumination optical device indicated by JP,2003-178951,A to the zoom lens 7, the optical system from the angle light flux formation part 2 of the illumination optical device indicated by JP,2003-178952,A to the variable power optical system 4, etc.

[0091]

By what (exposure process) the pattern for transfer which illuminated the mask (reticle) (Lighting Sub-Division process), and was formed in the mask in the exposure device concerning an above-mentioned embodiment using the projection optical system by the illumination optical device is exposed for to a photosensitive substrate. Micro devices (a semiconductor device, an image sensor, a liquid crystal display element, a thin film magnetic head, etc.) can be manufactured. Hereafter, by forming a predetermined circuit pattern in the wafer as a photosensitive substrate, etc. using the exposure device of an above-mentioned embodiment explains with reference to the flow chart of drawing 9 per example of the technique at the time of obtaining the semiconductor device as a micro device.

[0092]

First, in Step 301 of drawing 9, a metal membrane is vapor-deposited on the wafer of one lot. In the following step 302, photoresist is applied on the metal membrane on the wafer of the one lot. Then, in Step 303, exposure transfer of the image of the pattern on a mask is carried out to each shot region on the wafer of the one lot one by one via the projection optical system using the exposure device of an above-mentioned embodiment. Then, in the step 305 after development of the photoresist on the wafer of the one lot was performed in Step 304, By etching by using a resist pattern as a mask on the wafer of the one lot, the circuit pattern corresponding to the pattern on a mask is formed in each shot region on each wafer. Then, devices, such as a semiconductor device, are manufactured by performing formation of the circuit pattern of the upper layer, etc. According to the above-mentioned semiconductor device manufacturing method, the semiconductor device which has a very detailed circuit pattern can be obtained with a sufficient throughput.

[0093]

In the exposure device of an above-mentioned embodiment, the liquid crystal display element as a micro device can also be obtained by forming predetermined patterns (a circuit pattern, an electrode pattern, etc.) on a plate (glass substrate). Hereafter, with reference to the flow chart of drawing 10, it explains per example of the technique at this time. In drawing 10, what is called an optical lithography process of carrying out transfer exposure of the pattern of a mask to photosensitive substrates (glass substrate etc. in which the resist was applied) using the exposure device of an above-mentioned embodiment is performed by the pattern formation process 401. Of this optical lithography process, the prescribed pattern containing many electrodes etc. is formed on a photosensitive substrate. Then, by passing through each process, such as a developing process, an etching step, and a resist peeling process, a predetermined pattern is formed on a substrate and the exposed substrate shifts to the following light filter formation process 402.

[0094]

Next, in the light filter formation process 402. Many groups of three dots corresponding to R (Red), G (Green), and B (Blue) are arranged by matrix form, or form the light filter which arranged the group of three filters, R, G, and B, of a stripe to two or more horizontal scanning line directions. And 403 is performed for a cell assembler after the light filter formation process 402. By 403, a liquid crystal panel (liquid crystal cell) is assembled as a cell assembler using the substrate which has the prescribed pattern obtained by the pattern formation process 401, the light filter obtained with the light filter formation process 402, etc.

[0095]

In 403, a liquid crystal is poured in as a cell assembler between the substrate which has the prescribed pattern obtained by the pattern formation process 401, for example, and the light filter obtained with the light filter formation process 402, and he manufactures a liquid crystal panel (liquid crystal cell). Then, you attach each part articles in which the display action of the assembled liquid crystal panel (liquid crystal cell) is made to perform, such as an electric circuit and a back light, as a module assembler, and he makes it complete as a liquid crystal display element in 404. According to the manufacturing method of an above-mentioned liquid crystal display element, the liquid crystal display element which has a very detailed circuit pattern can be obtained with a sufficient throughput.
[0096]
Although KrF excimer laser light (wavelength: 248 nm) and ArF excimer laser light (wavelength: 193 nm) are used as exposing light in the above-mentioned embodiment, This invention can also be applied to other suitable laser light sources, for example, the F_2 laser light source etc. which supply a laser beam with a wavelength of 157 nm, without being limited to this. Although the above-mentioned embodiment explained this invention taking the case of the exposure device provided with the illumination optical device, it is clear that this invention is applicable to the common illumination optical device for illuminating irradiated planes other than a mask or a wafer.
[0097]
In an above-mentioned embodiment, the technique of filling the inside of the optical path between a projection optical system and a photosensitive substrate with the medium (typically liquid) which has a bigger refractive index than 1.1, and what is called an immersion method may be applied. In this case, as the technique of filling a liquid in the optical path between a projection optical system and a photosensitive substrate, The technique of filling a liquid locally currently indicated by the International-Publication number WO 99/No. 49504 gazette, The technique to which the stage holding the substrate of an exposure object which is indicated by JP,H6-124873,A is moved in a cistern, The liquid tub of a prescribed depth can be formed on a stage which is indicated by JP,H10-303114,A, and the technique of holding a substrate in it, etc. can be adopted.
[0098]
There is permeability over exposing light as a liquid, and a refractive index is high as much as possible, It is preferred to use a stable thing to the photoresist applied to the projection optical system or the substrate face, for example, when making KrF excimer laser light and ArF excimer laser light into exposing light, pure water and deionized water can be used as a liquid. An F_2 laser beam can be penetrated as a liquid, for example, what is necessary is just to use the liquid of fluorine systems, such as fault fluorine system oil, polyether, fluoridation (PFPE), when using an F_2 laser beam as exposing light.
[Brief Description of the Drawings]
[0099]
[Drawing 1]It is a figure showing roughly the entire configuration of the exposure device concerning the embodiment of this invention.
[Drawing 2]It is a figure showing roughly the internal configuration of the control unit in drawing 1.
[Drawing 3]It is a figure showing roughly the secondary light source of the shape of 5 poles formed in the backside focal plane of a micro fly eye lens, or its neighborhood.
[Drawing 4]It is a figure explaining an operation of a cone axicon system to the surface light source of the shape of 4 poles which constitutes a secondary light source.
[Drawing 5]It is a figure explaining a collaboration operation with the cone axicon system and zoom lens to a secondary 5 pole-like light source.
[Drawing 6]It is a perspective view showing the internal configuration of a polarization monitor of drawing 1 roughly.
[Drawing 7]It is a figure showing roughly the composition of the control unit concerning the 1st modification of this embodiment.
[Drawing 8]It is a figure showing roughly the important section composition of the control unit concerning the 2nd modification of this embodiment.
[Drawing 9]It is a flow chart of the technique at the time of obtaining the semiconductor device as a micro device.
[Drawing 10]It is a flow chart of the technique at the time of obtaining the liquid crystal display element as a micro device.
[Explanations of letters or numerals]
[0100]
1 Light source
5, 50, 51 control units
6 micro fly eye lens (fly eye lens)
7 Polarization monitor
7a Beam splitter
8 Condenser optical systems
9 Mask blinds
10 Image formation optical system
11 Fly eye lens
13 Rectangular prism (division element)
17 Polarization condition changing part
19 Detector
20 Diffraction optical element (light flux sensing element)
21 Afocal lens
23 Cone axicon system
24 Zoom lens
26 Condensing optical system
M Mask
PL Projection optical system
W Wafer

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[0099]
[Drawing 1]It is a figure showing roughly the entire configuration of the exposure device concerning the embodiment of this invention.
[Drawing 2]It is a figure showing roughly the internal configuration of the control unit in drawing 1.
[Drawing 3]It is a figure showing roughly the secondary light source of the shape of 5 poles formed in the backside focal plane of a micro fly eye lens, or its neighborhood.
[Drawing 4]It is a figure explaining an operation of a cone axicon system to the surface light source of the shape of 4 poles which constitutes a secondary light source.
[Drawing 5]It is a figure explaining a collaboration operation with the cone axicon system and zoom lens to a secondary 5 pole-like light source.
[Drawing 6]It is a perspective view showing the internal configuration of a polarization monitor of drawing 1 roughly.
[Drawing 7]It is a figure showing roughly the composition of the control unit concerning the 1st modification of this embodiment.
[Drawing 8]It is a figure showing roughly the important section composition of the control unit concerning the 2nd modification of this embodiment.
[Drawing 9]It is a flow chart of the technique at the time of obtaining the semiconductor device as a micro device.
[Drawing 10]It is a flow chart of the technique at the time of obtaining the liquid crystal display element as a micro device.

[Translation done.]

* NOTICES *

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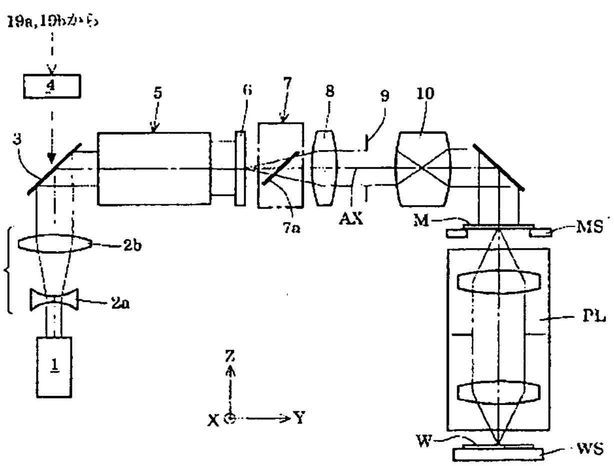
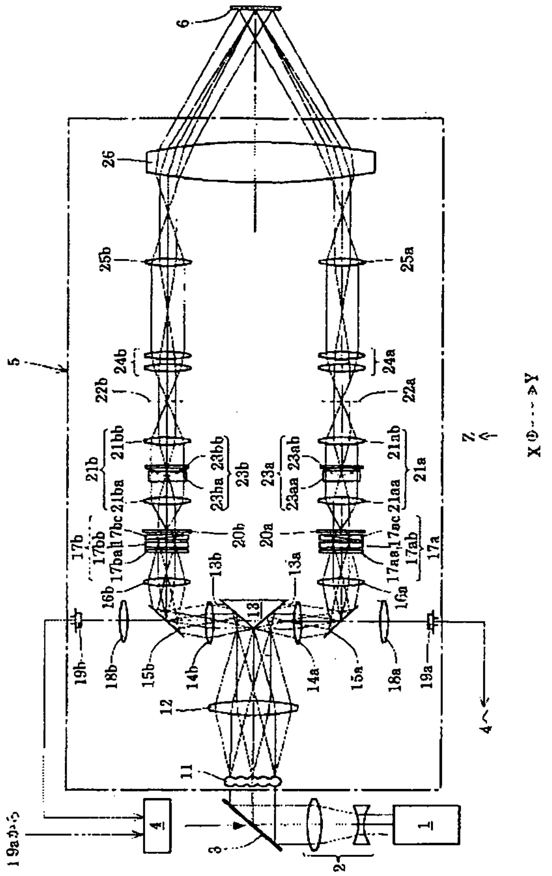
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

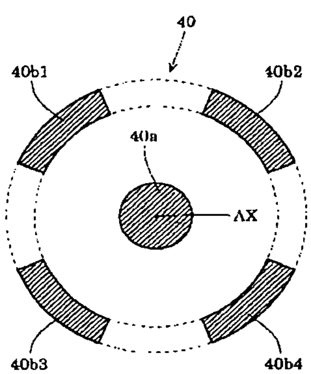
[Drawing 1]



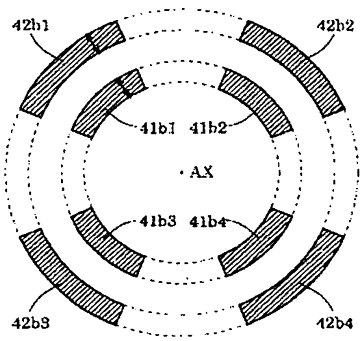
[Drawing 2]


6
26
25b
25a
24b
24a
22b
22a
5
21b
21bb
21ba
21a
21ab
21aa
23b
23ba
23bb
23a
23aa
23ab
20b
20a
17b
17bb
17bc
17ba
17a
17ab
17ac
17aa
16b
16a
13b
13a
13
19b
18b
15b
14b
14a
15a
18a
19a
12
11
4
1
3
2

[Drawing 3]

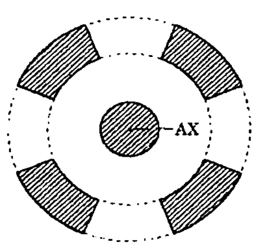

40
40b1
40b2
40a
AX
40b3
40b4

[Drawing 4]

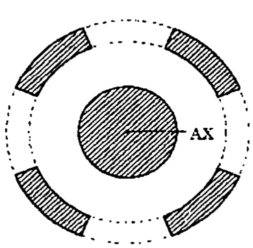


[Drawing 5]

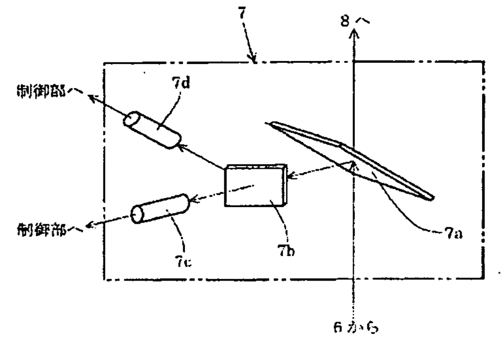
(a)



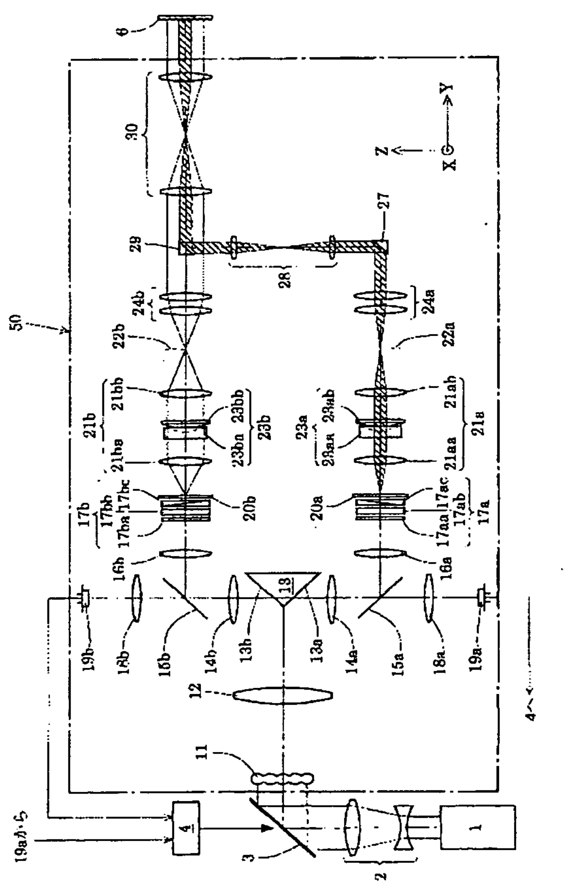
(b)



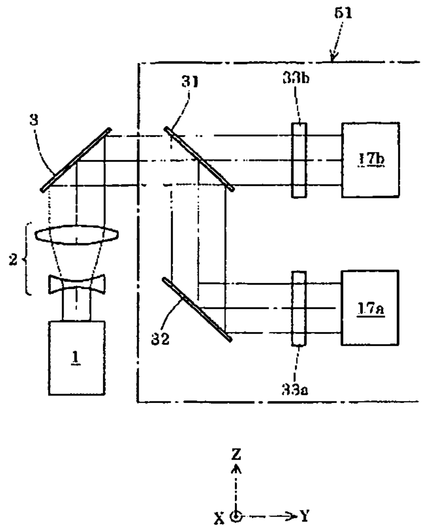
[Drawing 6]


7
8へ
制御部へ
7d
7a
7b
制御部へ
7c
6から

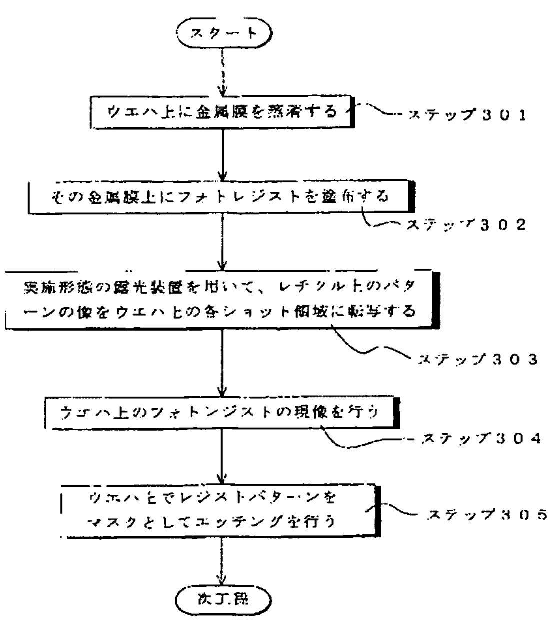
[Drawing 7]


6
50
30
Z
X
Y
29
27
28
24b
24a
22b
22a
21b
21bb
21ba
23b
23bb
23ba
21a
21ab
21aa
23a
23ab
23aa
20b
20a
17b
17bc
17bb
17ba
17a
17ac
17ab
17aa
16b
16a
13
13b
13a
14b
14a
15b
15a
18b
18a
19b
19a
12
11
4
1
2
3
4へ
19aから

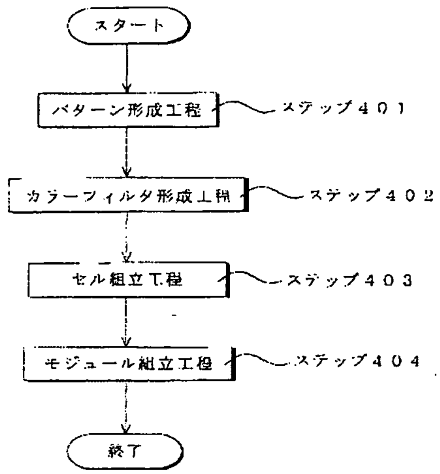
[Drawing 8]



[Drawing 9]



[Drawing 10]



[Translation done.]

CORRECTION OR AMENDMENT

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G03F 7/20 (2006. 01)
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[Claim(s)]
[Claim 1]
In an illumination optical device which illuminates an irradiated plane by light flux from a light source,
A division element for dividing light flux from said light source,
The 1st optical system for drawing the 1st light flux divided via said division element,
The 2nd optical system that became independent of said 1st optical system for drawing the 2nd different light flux from said 1st light flux divided via said division element,
An illumination equalization means for being arranged in an optical path between said light source and said division element, and equalizing illuminance distribution near said division element mostly,
A preparation,
An illumination optical device leading the 1st and 2nd light flux from said 1st optical system and said 2nd optical system to said irradiated plane.
[Claim 2]
Said 1st optical system is provided with the 1st light flux sensing element for changing entering light flux into light flux corresponding to the 1st field on an illumination pupil plane,
The illumination optical device according to claim 1, wherein said 2nd optical system is provided with the 2nd light flux sensing element for changing entering light flux into light flux corresponding to the 2nd field on said illumination pupil plane.
[Claim 3]
It has the Lighting Sub-Division pupil means forming for forming the Lighting Sub-Division pupil distribution which has light intensity distribution located in the 1st field on an illumination pupil plane, and the light intensity distribution located in the 2nd field,
Said Lighting Sub-Division pupil means forming,
Said division element,
Said 1st optical system for while having been divided and leading light flux to the 1st field on said illumination pupil plane via said division element,
Said 2nd optical system for leading light flux of another side divided via said division element to the 2nd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system,
The illumination optical device according to claim 2 having been arranged in an optical path between said division element and said illumination pupil plane, and having a composite element for compounding an optic axis of said 1st optical system, and an optic axis of said 2nd optical system.
[Claim 4]

An illumination optical device given in any 1 clause of Claims 1-3, wherein said division element carries out wavefront splitting of the light flux from said light source and leads it to said 1st optical system and said 2nd optical system.
[Claim 5]
An illumination optical device given in any 1 clause of Claims 1-4 characterized by comprising the following.
Two or more lens elements into which said illumination equalization means divides light flux from said light source in two dimensions.
A condenser lens for drawing light flux from a lens element of this plurality near said division element.

[Claim 6]
In an illumination optical device which illuminates an irradiated plane by light flux from a light source,
It has the Lighting Sub-Division pupil means forming for forming the Lighting Sub-Division pupil distribution which has light intensity distribution located in the 1st field on an illumination pupil plane, and the light intensity distribution located in the 2nd field,
Said Lighting Sub-Division pupil means forming,
A division element arranged in an optical path between said light source and said illumination pupil plane,
The 1st optical system for while having been divided and leading light flux to the 1st field on said illumination pupil plane via said division element,
The 2nd optical system for leading light flux of another side divided via said division element to the 2nd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system,
It is arranged in an optical path between said division element and said illumination pupil plane, and has a composite element for compounding an optic axis of said 1st optical system, and an optic axis of said 2nd optical system,
Said 1st optical system is provided with the 1st light flux sensing element for changing entering light flux into light flux corresponding to said 1st field,
An illumination optical device, wherein said 2nd optical system is provided with the 2nd light flux sensing element for changing entering light flux into light flux corresponding to said 2nd field.
[Claim 7]
The illumination optical device according to claim 6, wherein said Lighting Sub-Division pupil means forming is further provided with the 3rd optical system for leading light flux divided via said division element to the 3rd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system and said 2nd optical system.
[Claim 8]
In an illumination optical device which illuminates an irradiated plane by light flux from a light source,
The Lighting Sub-Division pupil means forming for forming the Lighting Sub-Division pupil distribution which has light intensity distribution located in the 1st field on an illumination pupil plane, and the light intensity distribution located in the 2nd field,
An illumination optical device provided with the Lighting Sub-Division pupil control means for performing control which changes control which changes form of said 1st field, and form of said 2nd field mutually-independent, and a polarization condition of light flux which passes through said 1st field and a polarization condition of light flux which passes through said 2nd field mutually-independent.
[Claim 9]
A division element for dividing light flux from said light source,
The 1st optical system for while having been divided and leading light flux to said 1st field on said illumination pupil plane via said division element,
The illumination optical device according to claim 8 provided with the 2nd optical system for leading light flux of another side divided via said division element to said 2nd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system.
[Claim 10]
The illumination optical device according to claim 9 having been arranged in an optical path between said light source and said division element, and having an illumination equalization means for equalizing illuminance distribution near said division element mostly.
[Claim 11]
The illumination optical device according to claim 9 or 10, wherein said division element carries out wavefront splitting of the light flux from said light source and leads it to said 1st optical system and said 2nd optical system.
[Claim 12]
The 1st light flux sensing element for changing into light flux corresponding to said 1st field light flux which said Lighting Sub-Division pupil means forming is arranged in an optical path of said 1st optical system, and enters, The 2nd light flux sensing element for changing into light flux corresponding to said 2nd field light flux which is arranged in an optical path of said 2nd optical system, and enters, An illumination optical device given in any 1 clause of Claims 9-11 having an optical integrator for forming said Lighting Sub-Division pupil distribution in said illumination pupil plane based on light flux from said 1st light flux sensing element, and light flux from said 2nd light flux sensing element.
[Claim 13]
The 1st shape change means for said Lighting Sub-Division pupil control means being arranged in an optical path of said 1st optical system, and changing form of said 1st field, An illumination optical device given in any 1 clause of Claims 9-12 having the 2nd shape change means for being arranged in an optical path of said 2nd optical system, and changing form of said 2nd field.
[Claim 14]
Said 1st shape change means has the 1st axicon system arranged in an optical path between said 1st light flux sensing element and said optical integrator,
Said 2nd shape change means has the 2nd axicon system arranged in an optical path between said 2nd light flux sensing element and said optical integrator,
The illumination optical device according to claim 13, wherein it has the 2nd prism characterized by comprising the following, respectively and an interval of said 1st prism and said 2nd prism is constituted by variable.
The 1st prism with which said 1st axicon system and said 2nd axicon system have a refracting interface of a concave section.
A refracting interface of said concave section of this 1st prism, and a refracting interface of a convex section formed almost complementarily.

[Claim 15]
Said 1st shape change means has the 1st variable power optical system arranged in an optical path between said 1st light flux sensing element and said optical integrator,
The illumination optical device according to claim 14, wherein said 2nd shape change means has the 2nd variable power optical system arranged in an optical path between said 2nd light flux sensing element and said optical integrator.
[Claim 16]
The 1st polarization condition alteration means for changing a polarization condition of light flux which said Lighting Sub-Division pupil control means is arranged in an optical path of said 1st optical system, and passes through said 1st field, An illumination optical device given in any 1 clause of Claims 9-15 having the 2nd polarization condition alteration means for changing a polarization condition of light flux which is arranged in an optical path of said 2nd optical system, and passes through said 2nd field.
[Claim 17]
It has a primacy phase component for changing a polarization direction of linear polarization which said 1st polarization condition alteration means is arranged in an optical path of said 1st optical system, and enters if needed,
The illumination optical device according to claim 16 having the 2nd phase-parts material for changing a polarization direction of linear polarization which said 2nd polarization condition alteration means is arranged in an optical path of said 2nd optical system, and enters if needed.
[Claim 18]
Said 1st polarization condition alteration means is constituted to an optical path of said 1st optical system, enabling free insertion and detachment, and it has the 1st depolarization element for unpolarized-light-izing entering light if needed,
The illumination optical device according to claim 16 or 17 constituting said 2nd polarization condition alteration means to an optical path of said 2nd optical system, enabling free insertion and detachment, and having the 2nd depolarization element for unpolarized-light-izing entering light if needed.
[Claim 19]
Said Lighting Sub-Division pupil means forming is provided with the 2nd light flux sensing element for changing into light flux corresponding to said 2nd field light flux which is arranged in the 1st light flux sensing element for changing into light flux corresponding to said 1st field light flux which is arranged in an optical path of said 1st optical system, and enters, and an optical path of said 2nd optical system, and enters,
A primacy phase component for changing a polarization direction of linear polarization which said 1st polarization condition alteration means is arranged in an optical path between said division element and said 1st light flux sensing element, and enters if needed, It has the 1st depolarization element for unpolarized-light-izing light which is arranged enabling free insertion and detachment and enters into said optical path between said division element and said 1st light flux sensing element if needed,
An illumination optical device given in any 1 clause of Claims 16-18 characterized by comprising the following.
The 2nd phase-parts material for changing a polarization direction of linear polarization which said 2nd polarization condition alteration means is arranged in an optical path between said division element and said 2nd light flux sensing element, and enters if needed.
The 2nd depolarization element for unpolarized-light-izing light which is arranged enabling free insertion and detachment and enters into said optical path between said division element and said 1st light flux sensing element if needed.

[Claim 20]
An illumination optical device given in any 1 clause of Claims 9-19 characterized by comprising the following.
The 1st light intensity alteration means for said Lighting Sub-Division pupil control means to change light intensity of light flux which passes through said 1st field.
The 2nd light intensity alteration means for changing light intensity of light flux which passes through said 2nd field.

[Claim 21]
The illumination optical device according to claim 20, wherein said 1st light intensity alteration means is arranged in an optical path of said 1st optical system and said 2nd light intensity alteration means is arranged in an optical path of said 2nd optical system.
[Claim 22]
Said 1st light intensity alteration means has selectively at least one dimming means which can be inserted and detached freely to an optical path of said 1st optical system, The illumination optical device according to claim 21, wherein said 2nd light intensity alteration means has selectively at least one dimming means which can be inserted and detached freely to an optical path of said 2nd optical system.
[Claim 23]
An illumination optical device given in any 1 clause of Claims 10-22, wherein said 1st light flux sensing element and said 2nd light flux sensing element are constituted exchangeable to an optical path, respectively.
[Claim 24]
An illumination optical device given in any 1 clause of Claims 6-23, wherein said 1st field is a field which includes an optic axis on said illumination pupil plane and said 2nd field is a field distant from said optic axis on said illumination pupil plane.
[Claim 25]
The illumination optical device according to claim 24, wherein said 2nd field has the shape of zona orbicularis, or the shape of plural poles.
[Claim 26]
An illumination optical device given in any 1 clause of Claims 12-25 having further a light guide optical system for leading light flux from said optical integrator to said irradiated plane.
[Claim 27]
An illumination optical device given in any 1 clause of Claims 6-26, wherein said Lighting Sub-Division pupil means forming is further provided with the 3rd optical system for leading light flux divided via said division element to the 3rd field on said illumination pupil plane in accordance with a different optical path from said 1st optical system and said 2nd optical system.
[Claim 28]

An exposure device equipping any 1 clause of Claims 6-27 for illuminating a mask with an illumination optical device of a description, and exposing a pattern of said mask on a photosensitive substrate.
[Claim 29]
It has further a projection optical system for forming an image of a pattern of said mask on said photosensitive substrate,
The exposure device according to claim 28, wherein a pupil surface of said illumination optical device is mostly positioned by conjugate with a pupil posion of said projection optical system.
[Claim 30]
An exposure device equipping any 1 clause of Claims 1-5 for illuminating a mask with an illumination optical device of a description, and exposing a pattern of said mask on a photosensitive substrate.
[Claim 31]
The Lighting Sub-Division process of illuminating a mask using an illumination optical device of a description in any 1 clause of Claims 1-27,
An exposure method including an exposure process which exposes a pattern of said mask on a photosensitive substrate.
[Claim 32]
Said exposure process includes a projection process of forming an image of a pattern of said mask on said photosensitive substrate using a projection optical system,
The exposure method according to claim 31, wherein a pupil surface of said illumination optical device is mostly positioned by conjugate with a pupil posion of said projection optical system.

[Translation done.]

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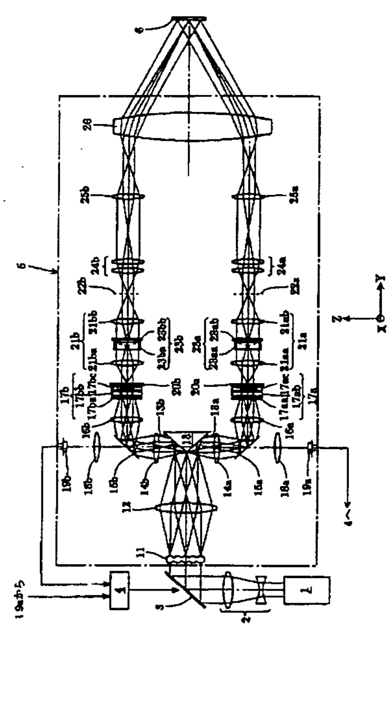
(54)【発明の名称】照明光学装置、露光装置、および露光方法

(57)【要約】
【課題】　露光装置に搭載された場合に、様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件、たとえば二次光源の形状や光強度や偏光状態などに関して多様性に富んだ照明条件を実現することのできる照明光学装置。
【解決手段】　光源（１）からの光束で被照射面を照明する照明光学装置。照明瞳面上の第１領域に位置する光強度分布と第２領域に位置する光強度分布とを有する照明瞳分布を形成するための照明瞳形成手段（２０～２６，６）と、第１領域の形状と第２領域の形状とを互いに独立に変更する制御と、第１領域を通過する光束の偏光状態と第２領域を通過する光束の偏光状態とを互いに独立に変更する制御とを行うための照明瞳制御手段（１７，２３，２４）とを備えている。
【選択図】　図２



【特許請求の範囲】
【請求項1】
光源からの光束で被照射面を照明する照明光学装置において、
照明瞳面上の第１領域に位置する光強度分布と第２領域に位置する光強度分布とを有する照明瞳分布を形成するための照明瞳形成手段と、
前記第１領域の形状と前記第２領域の形状とを互いに独立に変更する制御と、前記第１領域を通過する光束の偏光状態と前記第２領域を通過する光束の偏光状態とを互いに独立に変更する制御とを行うための照明瞳制御手段とを備えていることを特徴とする照明光学装置。
【請求項2】
前記光源からの光束を分割するための分割素子と、
前記分割素子を介して分割された一方の光束を前記照明瞳面上の前記第１領域へ導くための第１光学系と、
前記分割素子を介して分割された他方の光束を前記第１光学系とは異なる光路に沿って前記照明瞳面上の前記第２領域へ導くための第２光学系とを備えていることを特徴とする請求項１に記載の照明光学装置。
【請求項3】
前記光源と前記分割素子との間の光路中に配置されて、前記分割素子の近傍での照度分布をほぼ均一化するための照度均一化手段を備えていることを特徴とする請求項２に記載の照明光学装置。
【請求項4】
前記分割素子は、前記光源からの光束を波面分割して前記第１光学系および前記第２光学系へ導くことを特徴とする請求項２または３に記載の照明光学装置。
【請求項5】
前記照明瞳形成手段は、前記第１光学系の光路中に配置されて入射する光束を前記第１領域に対応する光束に変換するための第１光束変換素子と、前記第２光学系の光路中に配置されて入射する光束を前記第２領域に対応する光束に変換するための第２光束変換素子と、前記第１光束変換素子からの光束および前記第２光束変換素子からの光束に基づいて前記照明瞳面に前記照明瞳分布を形成するためのオプティカルインテグレータとを有することを特徴とする請求項２乃至４に記載の照明光学装置。
【請求項6】
前記照明瞳制御手段は、前記第１光学系の光路中に配置されて前記第１領域の形状を変更するための第１形状変更手段と、前記第２光学系の光路中に配置されて前記第２領域の形状を変更するための第２形状変更手段とを有することを特徴とする請求項２乃至５に記載の照明光学装置。
【請求項7】
前記第１形状変更手段は、前記第１光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第１アキシコン系を有し、
前記第２形状変更手段は、前記第２光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第２アキシコン系を有し、
前記第１アキシコン系および前記第２アキシコン系は、凹状断面の屈折面を有する第１プリズムと、該第１プリズムの前記凹状断面の屈折面とほぼ相補的に形成された凸状断面の屈折面を有する第２プリズムとをそれぞれ有し、前記第１プリズムと前記第２プリズムとの間隔は可変に構成されていることを特徴とする請求項６に記載の照明光学装置。
【請求項8】
前記第１形状変更手段は、前記第１光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第１変倍光学系を有し、
前記第２形状変更手段は、前記第２光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第２変倍光学系を有することを特徴とする請求項７に記載の照

明光学装置。
【請求項9】
前記照明瞳制御手段は、前記第１光学系の光路中に配置されて前記第１領域を通過する光束の偏光状態を変更するための第１偏光状態変更手段と、前記第２光学系の光路中に配置されて前記第２領域を通過する光束の偏光状態を変更するための第２偏光状態変更手段とを有することを特徴とする請求項２乃至８のいずれか１項に記載の照明光学装置。
【請求項10】
前記第１偏光状態変更手段は、前記第１光学系の光路中に配置されて入射する直線偏光の偏光方向を必要に応じて変化させるための第１位相部材を有し、
　前記第２偏光状態変更手段は、前記第２光学系の光路中に配置されて入射する直線偏光の偏光方向を必要に応じて変化させるための第２位相部材を有することを特徴とする請求項９に記載の照明光学装置。
【請求項11】
前記第１偏光状態変更手段は、前記第１光学系の光路に対して挿脱自在に構成されて、入射する光を必要に応じて非偏光化するための第１偏光解消素子を有し、
　前記第２偏光状態変更手段は、前記第２光学系の光路に対して挿脱自在に構成されて、入射する光を必要に応じて非偏光化するための第２偏光解消素子を有することを特徴とする請求項９または１０に記載の照明光学装置。
【請求項12】
前記照明瞳形成手段は、前記第１光学系の光路中に配置されて入射する光束を前記第１領域に対応する光束に変換するための第１光束変換素子と、前記第２光学系の光路中に配置されて入射する光束を前記第２領域に対応する光束に変換するための第２光束変換素子とを備え、
　前記第１偏光状態変更手段は、前記分割素子と前記第１光束変換素子との間の光路中に配置されて入射する直線偏光の偏光方向を必要に応じて変化させるための第１位相部材と、前記分割素子と前記第１光束変換素子との間の前記光路中に挿脱自在に配置されて入射する光を必要に応じて非偏光化するための第１偏光解消素子とを備え、
　前記第２偏光状態変更手段は、前記分割素子と前記第２光束変換素子との間の光路中に配置されて入射する直線偏光の偏光方向を必要に応じて変化させるための第２位相部材と、前記分割素子と前記第１光束変換素子との間の前記光路中に挿脱自在に配置されて入射する光を必要に応じて非偏光化するための第２偏光解消素子とを備えていることを特徴とする請求項９乃至１１に記載の照明光学装置。
【請求項13】
前記照明瞳制御手段は、前記第１領域を通過する光束の光強度を変更するための第１光強度変更手段と、前記第２領域を通過する光束の光強度を変更するための第２光強度変更手段とを有することを特徴とする請求項２乃至１２のいずれか１項に記載の照明光学装置。
【請求項14】
前記第１光強度変更手段は前記第１光学系の光路中に配置され、前記第２光強度変更手段は前記第２光学系の光路中に配置されていることを特徴とする請求項１３に記載の照明光学装置。
【請求項15】
前記第１光強度変更手段は前記第１光学系の光路に対して選択的に挿脱自在な少なくとも１つの減光手段を有し、前記第２光強度変更手段は前記第２光学系の光路に対して選択的に挿脱自在な少なくとも１つの減光手段を有することを特徴とする請求項１４に記載の照明光学装置。
【請求項16】
前記第１光束変換素子および前記第２光束変換素子は光路に対してそれぞれ交換可能に構成されていることを特徴とする請求項３乃至１５のいずれか１項に記載の照明光学装置。
【請求項17】
前記第１領域は前記照明瞳面上において光軸を含む領域であり、前記第２領域は前記照明

瞳面上において前記光軸から離れた領域であることを特徴とする請求項１乃至１６のいずれか１項に記載の照明光学装置。
【請求項18】
前記第２領域は輪帯状または複数極状であることを特徴とする請求項１７に記載の照明光学装置。
【請求項19】
前記オプティカルインテグレータからの光束を前記被照射面へ導くための導光光学系をさらに備えていることを特徴とする請求項３乃至１８のいずれか１項に記載の照明光学装置。
【請求項20】
光源からの光束で被照射面を照明する照明光学装置において、
照明瞳面上の第１領域に位置する光強度分布と第２領域に位置する光強度分布とを有する照明瞳分布を形成するための照明瞳形成手段を備え、
前記照明瞳形成手段は、
前記光源と前記照明瞳面との間の光路中に配置された分割素子と、
前記分割素子を介して分割された一方の光束を前記照明瞳面上の第１領域へ導くための第１光学系と、
前記分割素子を介して分割された他方の光束を前記第１光学系とは異なる光路に沿って前記照明瞳面上の第２領域へ導くための第２光学系と、
前記分割素子と前記照明瞳面との間の光路中に配置されて、前記第１光学系の光軸と前記第２光学系の光軸とを合成するための合成素子とを備え、
前記第１光学系は、入射する光束を前記第１領域に対応する光束に変換するための第１光束変換素子を備え、
前記第２光学系は、入射する光束を前記第２領域に対応する光束に変換するための第２光束変換素子を備えていることを特徴とする照明光学装置。
【請求項21】
前記照明瞳形成手段は、前記分割素子を介して分割された光束を前記第１光学系および前記第２光学系とは異なる光路に沿って前記照明瞳面上の第３領域へ導くための第３光学系をさらに備えていることを特徴とする請求項２乃至２０のいずれか１項に記載の照明光学装置。
【請求項22】
マスクを照明するための請求項１乃至２１のいずれか１項に記載の照明光学装置を備え、前記マスクのパターンを感光性基板上に露光することを特徴とする露光装置。
【請求項23】
前記マスクのパターンの像を前記感光性基板上に形成するための投影光学系をさらに備え、
前記照明光学装置の瞳面は、前記投影光学系の瞳位置とほぼ共役に位置決めされていることを特徴とする請求項２２に記載の露光装置。
【請求項24】
請求項１乃至２１のいずれか１項に記載の照明光学装置を用いてマスクを照明する照明工程と、
前記マスクのパターンを感光性基板上に露光する露光工程とを含むことを特徴とする露光方法。
【請求項25】
前記露光工程は、投影光学系を用いて前記マスクのパターンの像を前記感光性基板上に形成する投影工程を含み、
前記照明光学装置の瞳面は、前記投影光学系の瞳位置とほぼ共役に位置決めされることを特徴とする請求項２４に記載の露光方法。

【発明の詳細な説明】
【技術分野】
【0001】

本発明は、照明光学装置、露光装置、および露光方法に関し、特に半導体素子、撮像素子、液晶表示素子、薄膜磁気ヘッド等のマイクロデバイスをリソグラフィー工程で製造するための露光装置に好適な照明光学装置に関するものである。

【背景技術】

【0002】

この種の典型的な露光装置においては、光源から射出された光束が、オプティカルインテグレータとしてのフライアイレンズ（またはマイクロフライアイレンズ）を介して、多数の光源からなる実質的な面光源としての二次光源（一般には照明瞳面に形成される所定の光強度分布）を形成する。二次光源からの光束は、フライアイレンズの後側焦点面の近傍に配置された開口絞りを介して制限された後、コンデンサーレンズに入射する。

【0003】

コンデンサーレンズにより集光された光束は、所定のパターンが形成されたマスクを重畳的に照明する。マスクのパターンを透過した光は、投影光学系を介してウェハ上に結像する。こうして、ウェハ上には、マスクパターンが投影露光（転写）される。なお、マスクに形成されたパターンは高集積化されており、この微細パターンをウェハ上に正確に転写するにはウェハ上において均一な照度分布を得ることが不可欠である。

【0004】

そこで、フライアイレンズの後側焦点面に円形状の二次光源を形成し、その大きさを変化させて照明のコヒーレンシィσ（σ値＝開口絞り径／投影光学系の瞳径、あるいはσ値＝照明光学系の射出側開口数／投影光学系の入射側開口数）を変化させる技術が注目されている。また、フライアイレンズの後側焦点面に輪帯状や４極状の二次光源を形成し、投影光学系の焦点深度や解像力を向上させる技術が注目されている。

【発明の開示】

【発明が解決しようとする課題】

【0005】

上述のような従来の露光装置では、マスクのパターン特性に応じて、円形状の二次光源に基づく通常の円形照明を行ったり、輪帯状や４極状の二次光源に基づく変形照明（輪帯照明や４極照明）を行ったりしている。しかしながら、様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件、たとえば二次光源の形状や光強度や偏光状態などに関して多様性に富んだ照明条件を実現することができなかった。

【0006】

本発明は、前述の課題に鑑みてなされたものであり、たとえば露光装置に搭載された場合に、様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件、たとえば二次光源の形状や光強度や偏光状態などに関して多様性に富んだ照明条件を実現することのできる照明光学装置を提供することを目的とする。

【0007】

また、本発明は、たとえば様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件を実現することのできる照明光学装置を用いて、マスクのパターン特性に応じて実現された適切な照明条件のもとで良好な露光を行うことのできる露光装置および露光方法を提供することを目的とする。

【課題を解決するための手段】

【0008】

前記課題を解決するために、本発明の第１形態では、光源からの光束で被照射面を照明する照明光学装置において、

照明瞳面上の第１領域に位置する光強度分布と第２領域に位置する光強度分布とを有する照明瞳分布を形成するための照明瞳形成手段と、

前記第１領域の形状と前記第２領域の形状とを互いに独立に変更する制御と、前記第１領域を通過する光束の偏光状態と前記第２領域を通過する光束の偏光状態とを互いに独立に変更する制御とを行うための照明瞳制御手段とを備えていることを特徴とする照明光学装置を提供する。

【0009】
第１形態の好ましい態様によれば、前記光源からの光束を分割するための分割素子と、前記分割素子を介して分割された一方の光束を前記照明瞳面上の前記第１領域へ導くための第１光学系と、前記分割素子を介して分割された他方の光束を前記第１光学系とは異なる光路に沿って前記照明瞳面上の前記第２領域へ導くための第２光学系とを備えている。この場合、前記光源と前記分割素子との間の光路中に配置されて、前記分割素子の近傍での照度分布をほぼ均一化するための照度均一化手段を備えていることが好ましい。また、前記分割素子は、前記光源からの光束を波面分割して前記第１光学系および前記第２光学系へ導くことが好ましい。

【0010】
また、第１形態の好ましい態様によれば、前記照明瞳形成手段は、前記第１光学系の光路中に配置されて入射する光束を前記第１領域に対応する光束に変換するための第１光束変換素子と、前記第２光学系の光路中に配置されて入射する光束を前記第２領域に対応する光束に変換するための第２光束変換素子と、前記第１光束変換素子からの光束および前記第２光束変換素子からの光束に基づいて前記照明瞳面に前記照明瞳分布を形成するためのオプティカルインテグレータとを有する。また、前記照明瞳制御手段は、前記第１光学系の光路中に配置されて前記第１領域の形状を変更するための第１形状変更手段と、前記第２光学系の光路中に配置されて前記第２領域の形状を変更するための第２形状変更手段とを有することが好ましい。

【0011】
また、第１形態の好ましい態様によれば、前記第１形状変更手段は、前記第１光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第１アキシコン系を有し、前記第２形状変更手段は、前記第２光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第２アキシコン系を有し、前記第１アキシコン系および前記第２アキシコン系は、凹状断面の屈折面を有する第１プリズムと、該第１プリズムの前記凹状断面の屈折面とほぼ相補的に形成された凸状断面の屈折面を有する第２プリズムとをそれぞれ有し、前記第１プリズムと前記第２プリズムとの間隔は可変に構成されている。この場合、前記第１形状変更手段は、前記第１光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第１変倍光学系を有し、前記第２形状変更手段は、前記第２光束変換素子と前記オプティカルインテグレータとの間の光路中に配置された第２変倍光学系を有することが好ましい。

【0012】
また、第１形態の好ましい態様によれば、前記照明瞳制御手段は、前記第１光学系の光路中に配置されて前記第１領域を通過する光束の偏光状態を変更するための第１偏光状態変更手段と、前記第２光学系の光路中に配置されて前記第２領域を通過する光束の偏光状態を変更するための第２偏光状態変更手段とを有する。この場合、前記第１偏光状態変更手段は、前記第１光学系の光路中に配置されて入射する直線偏光の偏光方向を必要に応じて変化させるための第１位相部材を有し、前記第２偏光状態変更手段は、前記第２光学系の光路中に配置されて入射する直線偏光の偏光方向を必要に応じて変化させるための第２位相部材を有することが好ましい。また、前記第１偏光状態変更手段は、前記第１光学系の光路に対して挿脱自在に構成されて、入射する光を必要に応じて非偏光化するための第１偏光解消素子を有し、前記第２偏光状態変更手段は、前記第２光学系の光路に対して挿脱自在に構成されて、入射する光を必要に応じて非偏光化するための第２偏光解消素子を有することが好ましい。

【0013】
また、第１形態の好ましい態様によれば、前記照明瞳形成手段は、前記第１光学系の光路中に配置されて入射する光束を前記第１領域に対応する光束に変換するための第１光束変換素子と、前記第２光学系の光路中に配置されて入射する光束を前記第２領域に対応する光束に変換するための第２光束変換素子とを備え、前記第１偏光状態変更手段は、前記分割素子と前記第１光束変換素子との間の光路中に配置されて入射する直線偏光の偏光方

向を必要に応じて変化させるための第１位相部材と、前記分割素子と前記第１光束変換素子との間の前記光路中に挿脱自在に配置されて入射する光を必要に応じて非偏光化するための第１偏光解消素子とを備え、前記第２偏光状態変更手段は、前記分割素子と前記第２光束変換素子との間の光路中に配置されて入射する直線偏光の偏光方向を必要に応じて変化させるための第２位相部材と、前記分割素子と前記第１光束変換素子との間の前記光路中に挿脱自在に配置されて入射する光を必要に応じて非偏光化するための第２偏光解消素子とを備えている。

【0014】

また、第１形態の好ましい態様によれば、前記照明瞳制御手段は、前記第１領域を通過する光束の光強度を変更するための第１光強度変更手段と、前記第２領域を通過する光束の光強度を変更するための第２光強度変更手段とを有する。この場合、前記第１光強度変更手段は前記第１光学系の光路中に配置され、前記第２光強度変更手段は前記第２光学系の光路中に配置されていることが好ましい。また、この場合、前記第１光強度変更手段は前記第１光学系の光路に対して選択的に挿脱自在な少なくとも１つの減光手段を有し、前記第２光強度変更手段は前記第２光学系の光路に対して選択的に挿脱自在な少なくとも１つの減光手段を有することが好ましい。

【0015】

また、第１形態の好ましい態様によれば、前記第１光束変換素子および前記第２光束変換素子は光路に対してそれぞれ交換可能に構成されている。また、前記第１領域は前記照明瞳面上において光軸を含む領域であり、前記第２領域は前記照明瞳面上において前記光軸から離れた領域であることが好ましい。この場合、前記第２領域は輪帯状または複数極状であることが好ましい。また、前記オプティカルインテグレータからの光束を前記被照射面へ導くための導光光学系をさらに備えていることが好ましい。

【0016】

本発明の第２形態では、光源からの光束で被照射面を照明する照明光学装置において、

照明瞳面上の第１領域に位置する光強度分布と第２領域に位置する光強度分布とを有する照明瞳分布を形成するための照明瞳形成手段を備え、

前記照明瞳形成手段は、

前記光源と前記照明瞳面との間の光路中に配置された分割素子と、

前記分割素子を介して分割された一方の光束を前記照明瞳面上の第１領域へ導くための第１光学系と、

前記分割素子を介して分割された他方の光束を前記第１光学系とは異なる光路に沿って前記照明瞳面上の第２領域へ導くための第２光学系と、

前記分割素子と前記照明瞳面との間の光路中に配置されて、前記第１光学系の光軸と前記第２光学系の光軸とを合成するための合成素子とを備え、

前記第１光学系は、入射する光束を前記第１領域に対応する光束に変換するための第１光束変換素子を備え、

前記第２光学系は、入射する光束を前記第２領域に対応する光束に変換するための第２光束変換素子を備えていることを特徴とする照明光学装置を提供する。

【0017】

第２形態の好ましい態様によれば、前記照明瞳形成手段は、前記分割素子を介して分割された光束を前記第１光学系および前記第２光学系とは異なる光路に沿って前記照明瞳面上の第３領域へ導くための第３光学系をさらに備えている。

【0018】

本発明の第３形態では、マスクを照明するための第１形態または第２形態の照明光学装置を備え、前記マスクのパターンを感光性基板上に露光することを特徴とする露光装置を提供する。この場合、前記マスクのパターンの像を前記感光性基板上に形成するための投影光学系をさらに備え、前記照明光学装置の瞳面は、前記投影光学系の瞳位置とほぼ共役に位置決めされていることが好ましい。

【0019】

本発明の第4形態では、第1形態または第2形態の照明光学装置を用いてマスクを照明する照明工程と、前記マスクのパターンを感光性基板上に露光する露光工程とを含むことを特徴とする露光方法を提供する。この場合、前記露光工程は、投影光学系を用いて前記マスクのパターンの像を前記感光性基板上に形成する投影工程を含み、前記照明光学装置の瞳面は、前記投影光学系の瞳位置とほぼ共役に位置決めされることが好ましい。

【発明の効果】

【0020】

本発明の照明光学装置では、たとえば回折光学素子のような光束変換素子やマイクロフライアイレンズのようなオプティカルインテグレータなどの作用により、照明瞳面上の第1領域に位置する光強度分布と第2領域に位置する光強度分布とを有する照明瞳分布、たとえば5極状の二次光源を形成する。そして、たとえばアキシコン系や変倍光学系などの作用により、第1領域の形状と第2領域の形状とを互いに独立に変更する制御を行う。また、たとえば1/2波長板のような位相部材やデポラライザ(偏光解消素子)などの作用により、第1領域を通過する光束の偏光状態と第2領域を通過する光束の偏光状態とを互いに独立に変更する制御を行う。

【0021】

したがって、たとえば露光装置に本発明の照明光学装置を搭載した場合、様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件、たとえば二次光源の形状や光強度や偏光状態などに関して多様性に富んだ照明条件を実現することができる。また、本発明の照明光学装置を用いる露光装置および露光方法では、様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件を実現することができるので、マスクのパターン特性に応じて実現された適切な照明条件のもとで良好な露光を行うことができ、ひいては高いスループットで良好なデバイスを製造することができる。

【発明を実施するための最良の形態】

【0022】

本発明の実施形態を、添付図面に基づいて説明する。

図1は、本発明の実施形態にかかる露光装置の全体構成を概略的に示す図である。また、図2は、図1における制御ユニットの内部構成を概略的に示す図である。図1において、感光性基板であるウェハWの法線方向に沿ってZ軸を、ウェハWの面内において図1の紙面に平行な方向にY軸を、ウェハWの面内において図1の紙面に垂直な方向にX軸をそれぞれ設定している。

【0023】

図1を参照すると、本実施形態の露光装置は、露光光(照明光)を供給するための光源1を備えている。光源1として、たとえば248nmの波長の光を供給するKrFエキシマレーザ光源や193nmの波長の光を供給するArFエキシマレーザ光源などを用いることができる。光源1から+Z方向に沿って射出されたほぼ平行な光束は、X方向に沿って細長く延びた矩形状の断面を有し、一対のレンズ2aおよび2bからなるビームエキスパンダー2に入射する。各レンズ2aおよび2bは、図1の紙面内(YZ平面内)において負の屈折力および正の屈折力をそれぞれ有する。

【0024】

したがって、ビームエキスパンダー2に入射した光束は、図1の紙面内において拡大され、所定の矩形状の断面を有する光束に整形される。整形光学系としてのビームエキスパンダー2を介したほぼ平行な光束は、ミラー3で+Y方向に偏向された後、制御ユニット5へ導かれる。なお、ミラー3は、ミラー駆動部4の作用により光軸AXに対して傾動可能に構成されている。ミラー駆動部4は、後述する検出器19aおよび19bからの信号に基づいて、ミラー3の傾動を制御する。

【0025】

図2を参照すると、本実施形態の制御ユニット5へ導かれた光束は、たとえば縦横に且つ稠密に配列された多数の正レンズエレメントからなるフライアイレンズ11に入射する。フライアイレンズ11に入射した光束は、多数のレンズエレメントにより二次元的に分

割され、その後側焦点面またはその近傍に多数の光源を形成する。フライアイレンズ１１の後側焦点面またはその近傍に形成された多数光源からの光束は、コンデンサーレンズ１２を介して集光された後、その後側焦点位置またはその近傍にほぼ均一な照度分布を有する照野を形成する。

【0026】

コンデンサーレンズ１２の後側焦点位置またはその近傍には、分割素子としての直角プリズム１３が配置されている。したがって、コンデンサーレンズ１２を介して直角プリズム１３に入射した光束のうち、その第１反射面１３ａに入射した光束は－Ｚ方向に反射されて第１光学系へ導かれ、その第２反射面１３ｂに入射した光束は＋Ｚ方向に反射されて第２光学系へ導かれる。第１光学系と第２光学系とは基本的に同じ構成を有するが、後述する回折光学素子２０の特性だけが互いに相違している。

【0027】

そこで、図２において、第１光学系を構成する要素には参照番号に符号「ａ」を添付し、第２光学系を構成する対応要素には同じ参照番号に符号「ｂ」を添付している。以下、第１光学系および第２光学系の構成および作用の説明に際して、第２光学系の対応する参照符号などを括弧内に記している。第１光学系（第２光学系）へ導かれた光束は、リレーレンズ１４ａ（１４ｂ）を介して、ビームスプリッター１５ａ（１５ｂ）に入射する。ビームスプリッター１５ａ（１５ｂ）で＋Ｙ方向に反射された大部分の光束は、リレーレンズ１６ａ（１６ｂ）を介して、偏光状態変更部１７ａ（１７ｂ）に入射する。

【0028】

偏光状態変更部１７ａ（１７ｂ）は、光源側から順に、光路に対して挿脱可能に構成された１／４波長板１７ａａ（１７ｂａ）と、光路に対して挿脱可能に構成された１／２波長板１７ａｂ（１７ｂｂ）と、光路に対して挿脱可能に構成されたデポラライザ（非偏光化素子）１７ａｃ（１７ｂｃ）とにより構成されている。なお、偏光状態変更部１７ａ（１７ｂ）の詳細な構成および作用については後述する。

【0029】

一方、ビームスプリッター１５ａ（１５ｂ）を透過した光束は、リレーレンズ１８ａ（１８ｂ）を介して検出器１９ａ（１９ｂ）に達する。ここで、コンデンサーレンズ１２の後側焦点位置と検出器１９ａ（１９ｂ）の検出面とは、リレーレンズ１４ａ（１４ｂ）およびリレーレンズ１８ａ（１８ｂ）を介して、光学的にほぼ共役に配置されている。こうして、リレーレンズ１８ａ（１８ｂ）および検出器１９ａ（１９ｂ）は、第１光学系（第２光学系）へ導かれた光束の光量（光強度）を検出し、ひいては直角プリズム１３における光量分割比を検出するための光量検出系を構成している。

【0030】

検出器１９ａ（１９ｂ）の出力信号は、ミラー駆動部４に供給される。ミラー駆動部４は、上述したように、検出器１９ａおよび１９ｂからの信号に基づいてミラー３を所定角度だけ傾動させ、直角プリズム１３の近傍に形成される照野を光軸直交方向（Ｚ方向に）に平行移動させる。換言すると、ミラー駆動部４からの指令に基づくミラー３の傾動により、直角プリズム１３における光量分割比が変化し、ひいては第１光学系へ導かれる光束の光量（光強度）と第２光学系へ導かれる光束の光量（光強度）との比が変化する。

【0031】

偏光状態変更部１７ａ（１７ｂ）を通過した光束は、回折光学素子２０ａ（２０ｂ）を介して、アフォーカルレンズ２１ａ（２１ｂ）に入射する。ここで、直角プリズム１３の反射面１３ａ（１３ｂ）と回折光学素子２０ａ（２０ｂ）とは、リレーレンズ１４ａ（１４ｂ）およびリレーレンズ１６ａ（１６ｂ）を介して、光学的にほぼ共役に配置されている。また、アフォーカルレンズ２１ａ（２１ｂ）は、その前側焦点位置と回折光学素子２０ａ（２０ｂ）の位置とがほぼ一致し且つその後側焦点位置と図中破線で示す所定面２２ａ（２２ｂ）の位置とがほぼ一致するように設定されたアフォーカル系（無焦点光学系）である。

【0032】

一般に、回折光学素子は、基板に露光光（照明光）の波長程度のピッチを有する段差を形成することによって構成され、入射ビームを所望の角度に回折する作用を有する。具体的には、第１光学系の光路中に配置された第１回折光学素子２０ａは、矩形状の断面を有する平行光束が入射した場合に、そのファーフィールド（またはフラウンホーファー回折領域）に円形状の光強度分布を形成する機能を有する。一方、第２光学系の光路中に配置された第２回折光学素子２０ｂは、矩形状の断面を有する平行光束が入射した場合に、そのファーフィールド（またはフラウンホーファー回折領域）に４極状の光強度分布を形成する機能を有する。

【0033】

したがって、光束変換素子としての回折光学素子２０ａ（２０ｂ）に入射したほぼ平行光束は、アフォーカルレンズ２１ａ（２１ｂ）の瞳面またはその近傍に円形状（４極状）の光強度分布を形成した後、ほぼ平行光束となってアフォーカルレンズ２１ａ（２１ｂ）から射出される。なお、アフォーカルレンズ２１ａ（２１ｂ）の前側レンズ群２１ａａ（２１ｂａ）と後側レンズ群２１ａｂ（２１ｂｂ）との間の光路中においてその瞳面またはその近傍には、円錐アキシコン系２３ａ（２３ｂ）が配置されているが、その詳細な構成および作用については後述する。

【0034】

以下、説明を簡単にするために、円錐アキシコン系２３ａ（２３ｂ）の作用を無視して、基本的な構成および作用を説明する。アフォーカルレンズ２１ａ（２１ｂ）を介した光束は、σ値可変用のズームレンズ２４ａ（２４ｂ）およびリレーレンズ２５ａ（２５b）を介して、第１光学系（第２光学系）から射出される。第１光学系および第２光学系からそれぞれ射出された光束は、集光光学系２６を介して、オプティカルインテグレータとしてのマイクロフライアイレンズ（またはフライアイレンズ）６に入射する。

【0035】

なお、制御ユニット５において、フライアイレンズ１１の入射面と、直角プリズム１３の反射面１３ａ（１３ｂ）と、検出器１９ａ（１９ｂ）の検出面と、回折光学素子２０ａ（２０ｂ）と、所定面２２ａ（２２b）と、リレーレンズ２５ａ（２５ｂ）の後側焦点面（あるいは集光光学系２６の前側焦点面）とが光学的にほぼ共役になっている。また、フライアイレンズ１１の後側焦点面（あるいは射出面）と、ビームスプリッター１５ａ（１５ｂ）と、円錐アキシコン系２３ａ（２３ｂ）と、ズームレンズ２４ａ（２４ｂ）の後側焦点面（あるいはリレーレンズ２５ａ（２５ｂ）の前側焦点面）とが光学的にほぼ共役になっている。

【0036】

マイクロフライアイレンズ６は、たとえば縦横に且つ稠密に配列された多数の正屈折力を有する微小レンズからなる光学素子である。一般に、マイクロフライアイレンズは、たとえば平行平面板にエッチング処理を施して微小レンズ群を形成することによって構成される。ここで、マイクロフライアイレンズを構成する各微小レンズは、フライアイレンズを構成する各レンズエレメントよりも微小である。また、マイクロフライアイレンズは、互いに隔絶されたレンズエレメントからなるフライアイレンズとは異なり、多数の微小レンズ（微小屈折面）が互いに隔絶されることなく一体的に形成されている。

【0037】

しかしながら、正屈折力を有するレンズ要素が縦横に配置されている点でマイクロフライアイレンズはフライアイレンズと同じ波面分割型のオプティカルインテグレータである。なお、所定面２２ａ（２２ｂ）の位置はズームレンズ２４ａ（２４ｂ）の前側焦点位置またはその近傍に配置され、ズームレンズ２４ａ（２４ｂ）の後側焦点位置とリレーレンズ２５ａ（２５ｂ）の前側焦点位置とはほぼ一致している。さらに、リレーレンズ２５ａ（２５ｂ）の後側焦点位置は集光光学系２６の前側焦点面またはその近傍に配置され、集光光学系２６の後側焦点位置またはその近傍にマイクロフライアイレンズ６の入射面が配置されている。

【0038】

換言すると、ズームレンズ２４ａ（２４ｂ）とリレーレンズ２５ａ（２５ｂ）と集光光学系２６とは、所定面２２ａ（２２ｂ）とマイクロフライアイレンズ６の入射面とを実質的にフーリエ変換の関係に配置し、ひいてはアフォーカルレンズ２１ａ（２１ｂ）の瞳面とマイクロフライアイレンズ６の入射面とを光学的にほぼ共役に配置している。したがって、マイクロフライアイレンズ６の入射面上には、第１光学系中の第１アフォーカルレンズ２１ａの瞳面またはその近傍に形成される円形状の光強度分布と、第２光学系中の第２アフォーカルレンズ２１ｂの瞳面またはその近傍に形成される４極状の光強度分布との合成からなる５極状の照野が形成される。この５極状の照野の全体形状は、ズームレンズ２４ａ（２４ｂ）の焦点距離に依存して相似的に変化する。

【0039】

マイクロフライアイレンズ６を構成する各微小レンズは、マスクＭ上において形成すべき照野の形状（ひいてはウェハＷ上において形成すべき露光領域の形状）と相似な矩形状の断面を有する。マイクロフライアイレンズ６に入射した光束は多数の微小レンズにより二次元的に分割され、その後側焦点面またはその近傍に（ひいては照明瞳面に）、マイクロフライアイレンズ６の入射面に形成される照野とほぼ同じ光強度分布を有する二次光源、すなわち図３に示すように例えば光軸ＡＸを中心とした円形状の実質的な面光源４０ａと、例えば光軸ＡＸに関して対称的に配置された４つの円弧状の実質的な面光源４０ｂ１～４０ｂ４とからなる５極状の二次光源４０が形成される。

【0040】

マイクロフライアイレンズ６の後側焦点面またはその近傍に形成された５極状の二次光源（照明瞳分布）からの光束は、ビームスプリッター７ａおよびコンデンサー光学系８を介した後、マスクブラインド９を重畳的に照明する。こうして、照明視野絞りとしてのマスクブラインド９には、マイクロフライアイレンズ６を構成する各微小レンズの形状と焦点距離とに応じた矩形状の照野が形成される。なお、ビームスプリッター７ａを内蔵する偏光モニター７の内部構成および作用については後述する。マスクブラインド９の矩形状の開口部（光透過部）を介した光束は、結像光学系１０の集光作用を受けた後、所定のパターンが形成されたマスクＭを重畳的に照明する。

【0041】

すなわち、結像光学系１０は、マスクブラインド９の矩形状開口部の像をマスクＭ上に形成することになる。マスクステージＭＳにより保持されたマスクＭのパターンを透過した光束は、投影光学系ＰＬを介して、ウェハステージＷＳにより保持されたウェハ（感光性基板）Ｗ上にマスクパターンの像を形成する。ここで、マイクロフライアイレンズ６の後側焦点面またはその近傍の照明瞳面は、投影光学系ＰＬの瞳位置とほぼ共役に位置決めされている。こうして、投影光学系ＰＬの光軸ＡＸと直交する平面（ＸＹ平面）内においてウェハＷを二次元的に駆動制御しながら一括露光またはスキャン露光を行うことにより、ウェハＷの各露光領域にはマスクＭのパターンが逐次露光される。

【0042】

なお、偏光状態変更部１７ａ（１７ｂ）において、１／４波長板１７ａａ（１７ｂａ）は、光軸ＡＸを中心として結晶光学軸が回転自在に構成されて、入射する楕円偏光の光を直線偏光の光に変換する。また、１／２波長板１７ａｂ（１７ｂｂ）は、光軸ＡＸを中心として結晶光学軸が回転自在に構成されて、入射する直線偏光の偏光面を変化させる。また、デポラライザ１７ａｃ（１７ｂｃ）は、相補的な形状を有する楔形状の水晶プリズムと楔形状の石英プリズムとにより構成されている。水晶プリズムと石英プリズムとは、一体的なプリズム組立体として、照明光路に対して挿脱自在に構成されている。

【0043】

光源１としてＫｒＦエキシマレーザ光源やＡｒＦエキシマレーザ光源を用いる場合、これらの光源から射出される光は典型的には９５％以上の偏光度を有し、１／４波長板１７ａａ（１７ｂａ）にはほぼ直線偏光の光が入射する。しかしながら、光源１と偏光状態変更部１７ａ（１７ｂ）との間の光路中に裏面反射鏡としての直角プリズムが介在する場合、入射する直線偏光の偏光面がＰ偏光面またはＳ偏光面に一致していないと、直角プリズ

ムでの全反射により直線偏光が楕円偏光に変わる。

【0044】

偏光状態変更部１７ａ（１７ｂ）では、たとえば直角プリズムでの全反射に起因して楕円偏光の光が入射しても、１／４波長板１７ａａ（１７ｂａ）の作用により変換された直線偏光の光が１／２波長板１７ａｂ（１７ｂｂ）に入射する。１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸が入射する直線偏光の偏光面に対して０度または９０度の角度をなすように設定された場合、１／２波長板１７ａｂ（１７ｂｂ）に入射した直線偏光の光は偏光面が変化することなくそのまま通過する。

【0045】

また、１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸が入射する直線偏光の偏光面に対して４５度の角度をなすように設定された場合、１／２波長板１７ａｂ（１７ｂｂ）に入射した直線偏光の光は偏光面が９０度だけ変化した直線偏光の光に変換される。さらに、デポラライザ１７ａｃ（１７ｂｃ）の水晶プリズムの結晶光学軸が入射する直線偏光の偏光面に対して４５度の角度をなすように設定された場合、水晶プリズムに入射した直線偏光の光は非偏光状態の光に変換（非偏光化）される。

【0046】

偏光状態変更部１７ａ（１７ｂ）では、デポラライザ１７ａｃ（１７ｂｃ）が照明光路中に位置決めされたときに水晶プリズムの結晶光学軸が入射する直線偏光の偏光面に対して４５度の角度をなすように構成されている。ちなみに、水晶プリズムの結晶光学軸が入射する直線偏光の偏光面に対して０度または９０度の角度をなすように設定された場合、水晶プリズムに入射した直線偏光の光は偏光面が変化することなくそのまま通過する。また、１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸が入射する直線偏光の偏光面に対して２２．５度の角度をなすように設定された場合、１／２波長板１７ａｂ（１７ｂｂ）に入射した直線偏光の光は、偏光面が変化することなくそのまま通過する直線偏光成分と偏光面が９０度だけ変化した直線偏光成分とを含む非偏光状態の光に変換される。

【0047】

偏光状態変更部１７ａ（１７ｂ）では、上述したように、直線偏光の光が１／２波長板１７ａｂ（１７ｂｂ）に入射するが、以下の説明を簡単にするために、図２においてＺ方向に偏光方向（電場の方向）を有する直線偏光（以下、「Ｚ方向偏光」と称する）の光が１／２波長板１７ａｂ（１７ｂｂ）に入射するものとする。デポラライザ１７ａｃ（１７ｂｃ）を照明光路中に位置決めした場合、１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸を入射するＺ方向偏光の偏光面（偏光方向）に対して０度または９０度の角度をなすように設定すると、１／２波長板１７ａｂ（１７ｂｂ）に入射したＺ方向偏光の光は偏光面が変化することなくＺ方向偏光のまま通過してデポラライザ１７ａｃ（１７ｂｃ）の水晶プリズムに入射する。水晶プリズムの結晶光学軸は入射するＺ方向偏光の偏光面に対して４５度の角度をなすように設定されているので、水晶プリズムに入射したＺ方向偏光の光は非偏光状態の光に変換される。

【0048】

水晶プリズムを介して非偏光化された光は、光の進行方向を補償するためのコンペンセータとしての石英プリズムを介して、非偏光状態で回折光学素子２０ａ（２０ｂ）に入射する。一方、１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸を入射するＺ方向偏光の偏光面に対して４５度の角度をなすように設定すると、１／２波長板１７ａｂ（１７ｂｂ）に入射したＺ方向偏光の光は偏光面が９０度だけ変化し、図２においてＸ方向に偏光方向（電場の方向）を有する直線偏光（以下、「Ｘ方向偏光」と称する）の光になってデポラライザ１７ａｃ（１７ｂｃ）の水晶プリズムに入射する。水晶プリズムの結晶光学軸は入射するＸ方向偏光の偏光面に対しても４５度の角度をなすように設定されているので、水晶プリズムに入射したＸ方向偏光の光は非偏光状態の光に変換され、石英プリズムを介して、非偏光状態で回折光学素子２０ａ（２０ｂ）に入射する。

【0049】

これに対し、デポラライザ１７ａｃ（１７ｂｃ）を照明光路から退避させた場合、１／

２波長板１７ａｂ（１７ｂｂ）の結晶光学軸を入射するＺ方向偏光の偏光面に対して０度または９０度の角度をなすように設定すると、１／２波長板１７ａｂ（１７ｂｂ）に入射したＺ方向偏光の光は偏光面が変化することなくＺ方向偏光のまま通過し、Ｚ方向偏光状態で回折光学素子２０ａ（２０ｂ）に入射する。一方、１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸を入射するＺ方向偏光の偏光面に対して４５度の角度をなすように設定すると、１／２波長板１７ａｂ（１７ｂｂ）に入射したＺ方向偏光の光は偏光面が９０度だけ変化してＸ方向偏光の光になり、Ｘ方向偏光状態で回折光学素子２０ａ（２０ｂ）に入射する。

【0050】

以上のように、偏光状態変更部１７ａ（１７ｂ）では、デポラライザ１７ａｃ（１７ｂｃ）を照明光路中に挿入して位置決めすることにより、非偏光状態の光を回折光学素子２０ａ（２０ｂ）に入射させることができる。また、デポラライザ１７ａｃ（１７ｂｃ）を照明光路から退避させ且つ１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸を入射するＺ方向偏光の偏光面に対して０度または９０度の角度をなすように設定することにより、Ｚ方向偏光状態の光を回折光学素子２０ａ（２０ｂ）に入射させることができる。さらに、デポラライザ１７ａｃ（１７ｂｃ）を照明光路から退避させ且つ１／２波長板１７ａｂ（１７ｂｂ）の結晶光学軸を入射するＺ方向偏光の偏光面に対して４５度をなすように設定することにより、Ｘ方向偏光状態の光を回折光学素子２０ａ（２０ｂ）に入射させることができる。

【0051】

換言すれば、１／４波長板１７ａａ（１７ｂａ）と１／２波長板１７ａｂ（１７ｂｂ）とデポラライザ１７ａｃ（１７ｂｃ）とからなる偏光状態変更部１７ａ（１７ｂ）の作用により、回折光学素子２０ａ（２０ｂ）への入射光の偏光状態を、ひいては二次光源４０の円形状の面光源４０ａ（４極状の面光源４０ｂ１～４０ｂ４）を通過する光の偏光状態を、直線偏光状態と非偏光状態との間で切り換えることができ、直線偏光状態の場合には互いに直交する偏光状態間（Ｚ方向偏光とＸ方向偏光との間）で切り換えることができる。

【0052】

また、一般的には、１／２波長板１７ａｂ（１７ｂｂ）の作用により、回折光学素子２０ａ（２０ｂ）への入射光の偏光状態を、任意方向に偏光方向を有する直線偏光状態に設定することもできる。さらに、偏光状態変更部１７ａ（１７ｂ）では、１／２波長板１７ａｂ（１７ｂｂ）およびデポラライザ１７ａｃ（１７ｂｃ）をともに照明光路から退避させ、且つ１／４波長板１７ａａ（１７ｂａ）の結晶光学軸を入射する楕円偏光に対して所定の角度をなすように設定することにより、円偏光状態の光を回折光学素子２０ａ（２０ｂ）に入射させることができる。

【0053】

次に、円錐アキシコン系２３ａ（２３ｂ）は、光源側から順に、光源側（光入射側）に平面を向け且つマスク側（光射出側）に凹円錐状の屈折面を向けた第１プリズム部材２３ａａ（２３ｂａ）と、マスク側に平面を向け且つ光源側に凸円錐状の屈折面を向けた第２プリズム部材２３ａｂ（２３ｂｂ）とから構成されている。そして、第１プリズム部材２３ａａ（２３ｂａ）の凹円錐状の屈折面と第２プリズム部材２３ａｂ（２３ｂｂ）の凸円錐状の屈折面とは、互いに当接可能なように相補的に形成されている。また、第１プリズム部材２３ａａ（２３ｂａ）および第２プリズム部材２３ａｂ（２３ｂｂ）のうち少なくとも一方の部材が光軸ＡＸに沿って移動可能に構成され、第１プリズム部材２３ａａ（２３ｂａ）の凹円錐状の屈折面と第２プリズム部材２３ａｂ（２３ｂｂ）の凸円錐状の屈折面との間隔が可変に構成されている。

【0054】

ここで、第１プリズム部材２３ａａ（２３ｂａ）の凹円錐状屈折面と第２プリズム部材２３ａｂ（２３ｂｂ）の凸円錐状屈折面とが互いに当接している状態では、円錐アキシコン系２３ａ（２３ｂ）は平行平面板として機能し、形成される二次光源４０を構成する円

形状（４極状）の面光源４０ａ（４０ｂ）に及ぼす影響はない。しかしながら、第１プリズム部材２３ａａ（２３ｂａ）の凹円錐状屈折面と第２プリズム部材２３ａｂ（２３ｂｂ）の凸円錐状屈折面とを離間させると、円錐アキシコン系２３ａ（２３ｂ）は、いわゆるビームエキスパンダーとして機能する。したがって、円錐アキシコン系２３ａ（２３ｂ）の間隔の変化に伴って、所定面２２ａ（２２ｂ）への入射光束の角度は変化する。

【0055】

図４は、二次光源を構成する４極状の面光源に対する円錐アキシコン系の作用を説明する図である。図４を参照すると、第２光学系中の円錐アキシコン系２３ｂの間隔が零で且つズームレンズ２４ｂの焦点距離が最小値に設定された状態（以下、「標準状態」という）で形成された最も小さい４極状の面光源４１ｂ１～４１ｂ４が、円錐アキシコン系２３ｂの間隔を零から所定の値まで拡大させることにより、その幅（外接円の直径である外径と内接円の直径である内径との差の１／２：図中両方向矢印で示す）が変化することなく、その外径および内径がともに拡大された４極状の面光源４２ｂ１～４２ｂ４に変化する。換言すると、円錐アキシコン系２３ｂの作用により、４極状の面光源の幅が変化することなく、その輪帯比（内径／外径）および大きさ（外径）がともに変化する。

【0056】

一方、図示を省略するが、ズームレンズ２４ｂの標準状態で形成された４極状の面光源は、ズームレンズ２４ｂの焦点距離を最小値から所定の値へ拡大させることにより、その全体形状が相似的に拡大された４極状の面光源に変化する。換言すると、ズームレンズ２４ｂの変倍作用により、４極状の面光源４０ｂ１～４０ｂ４の全体が相似的に拡大または縮小され、その輪帯比が変化することなく、その幅および大きさ（外径）がともに変化する。同様に、第１光学系中のズームレンズ２４ａの変倍作用により、円形状の面光源４０ａが相似的に拡大または縮小される。なお、第１光学系中の円錐アキシコン系２３ａの作用により、必要に応じて円形状の面光源４０ａを輪帯状の面光源に変換し、その幅（外径と内径との差の１／２）を変化させることなく、その輪帯比（内径／外径）および大きさ（外径）をともに変化させることもできる。

【0057】

図５は、５極状の二次光源に対する円錐アキシコン系とズームレンズとの協働作用を説明する図である。本実施形態では、第１光学系中のズームレンズ２４ａの変倍作用により、図５（ａ）に示すように円形状の面光源を比較的小さくしたり、図５（ｂ）に示すように円形状の面光源を比較的大きくしたりすることができる。また、第２光学系中の円錐アキシコン系２３ｂとズームレンズ２４ｂとの協働作用により、大きさ（外径）を一定に保ちつつ、図５（ａ）に示すように４極状の面光源の幅を比較的大きくしたり、図５（ｂ）に示すように４極状の面光源の幅を比較的小さくしたりすることができる。

【0058】

すなわち、図５に示す例に限定されることなく、一般的に、第１光学系中のズームレンズ２４ａの変倍作用により、４極状の面光源とは独立して円形状の面光源を相似的に拡大または縮小することができる。また、第２光学系中の円錐アキシコン系２３ｂとズームレンズ２４ｂとの協働作用により、円形状の面光源とは独立して、４極状の面光源の幅、輪帯比（内径／外径）、大きさ（外径）などの形状パラメータを変化させることができる。さらに、必要に応じて、第１光学系中の円錐アキシコン系２３ａとズームレンズ２４ａとの協働作用により、円形状の面光源を輪帯状の面光源に変換し、その幅、輪帯比（内径／外径）、大きさ（外径）などの形状パラメータを変化させることができる。

【0059】

図６は、図１の偏光モニターの内部構成を概略的に示す斜視図である。図６を参照すると、偏光モニター７は、マイクロフライアイレンズ６とコンデンサー光学系８との間の光路中に配置された第１ビームスプリッター７ａを備えている。第１ビームスプリッター７ａは、たとえば石英ガラスにより形成されたノンコートの平行平面板（すなわち素ガラス）の形態を有し、入射光の偏光状態とは異なる偏光状態の反射光を光路から取り出す機能を有する。

【0060】
第１ビームスプリッター７ａにより光路から取り出された光は、第２ビームスプリッター７ｂに入射する。第２ビームスプリッター７ｂは、第１ビームスプリッター７ａと同様に、例えば石英ガラスにより形成されたノンコートの平行平面板の形態を有し、入射光の偏光状態とは異なる偏光状態の反射光を発生させる機能を有する。そして、第１ビームスプリッター７ａに対するＰ偏光が第２ビームスプリッター７ｂに対するＳ偏光になり、且つ第１ビームスプリッター７ａに対するＳ偏光が第２ビームスプリッター７ｂに対するＰ偏光になるように設定されている。
【0061】
また、第２ビームスプリッター７ｂを透過した光は第１光強度検出器７ｃにより検出され、第２ビームスプリッター７ｂで反射された光は第２光強度検出器７ｄにより検出される。第１光強度検出器７ｃおよび第２光強度検出器７ｄの出力は、それぞれ制御部（不図示）に供給される。制御部は、偏光状態変更部１７ａ（１７ｂ）を構成する１／４波長板１７ａａ（１７ｂａ）、１／２波長板１７ａｂ（１７ｂｂ）およびデポラライザ１７ａｃ（１７ｂｃ）を必要に応じて駆動する。
【0062】
上述のように、第１ビームスプリッター７ａおよび第２ビームスプリッター７ｂにおいて、Ｐ偏光に対する反射率とＳ偏光に対する反射率とが実質的に異なっている。したがって、偏光モニター７では、第１ビームスプリッター７ａからの反射光が、例えば第１ビームスプリッター７ａへの入射光の１０％程度のＳ偏光成分（第１ビームスプリッター７ａに対するＳ偏光成分であって第２ビームスプリッター７ｂに対するＰ偏光成分）と、例えば第１ビームスプリッター７ａへの入射光の１％程度のＰ偏光成分（第１ビームスプリッター７ａに対するＰ偏光成分であって第２ビームスプリッター７ｂに対するＳ偏光成分）とを含むことになる。
【0063】
また、第２ビームスプリッター７ｂからの反射光は、例えば第１ビームスプリッター７ａへの入射光の１０％×１％＝０．１％程度のＰ偏光成分（第１ビームスプリッター７ａに対するＰ偏光成分であって第２ビームスプリッター７ｂに対するＳ偏光成分）と、例えば第１ビームスプリッター７ａへの入射光の１％×１０％＝０．１％程度のＳ偏光成分（第１ビームスプリッター７ａに対するＳ偏光成分であって第２ビームスプリッター７ｂに対するＰ偏光成分）とを含むことになる。
【0064】
こうして、偏光モニター７では、第１ビームスプリッター７ａが、その反射特性に応じて、入射光の偏光状態とは異なる偏光状態の反射光を光路から取り出す機能を有する。その結果、第２ビームスプリッター７ｂの偏光特性による偏光変動の影響を僅かに受けるものの、第１光強度検出器７ｃの出力（第２ビームスプリッター７ｂの透過光の強度に関する情報、すなわち第１ビームスプリッター７ａからの反射光とほぼ同じ偏光状態の光の強度に関する情報）に基づいて、第１ビームスプリッター７ａへの入射光の偏光状態（偏光度）を、ひいてはマスクＭやウェハＷへの照明光の偏光状態を検知することができる。
【0065】
また、偏光モニター７では、第１ビームスプリッター７ａに対するＰ偏光が第２ビームスプリッター７ｂに対するＳ偏光になり且つ第１ビームスプリッター７ａに対するＳ偏光が第２ビームスプリッター７ｂに対するＰ偏光になるように設定されている。その結果、第２光強度検出器７ｄの出力（第１ビームスプリッター７ａおよび第２ビームスプリッター７ｂで順次反射された光の強度に関する情報）に基づいて、第１ビームスプリッター７ａへの入射光の偏光状態の変化の影響を実質的に受けることなく、第１ビームスプリッター７ａへの入射光の光量（強度）を、ひいてはマスクＭへの照明光の光量を検知することができる。
【0066】
こうして、偏光モニター７を用いて、第１ビームスプリッター７ａへの入射光の偏光状

態を検知し、ひいてはマスクＭへの照明光が所望の非偏光状態、直線偏光状態または円偏光状態になっているか否かを判定することができる。そして、制御部が偏光モニター７の検知結果に基づいてマスクＭ（ひいてはウェハＷ）への照明光が所望の非偏光状態、直線偏光状態または円偏光状態になっていないことを確認した場合、偏光状態変更部１７ａ（１７ｂ）を構成する１／４波長板１７ａａ（１７ｂａ）、１／２波長板１７ａｂ（１７ｂｂ）およびデポラライザ１７ａｃ（１７ｂｃ）を駆動調整し、マスクＭへの照明光の状態を所望の非偏光状態、直線偏光状態または円偏光状態に調整することができる。

【0067】

本実施形態では、上述したように、直角プリズム１３が、光源１からの光束を波面分割して第１光学系（１４ａ～２５ａ）および第２光学系（１４ｂ～２５ｂ）へ導くための分割素子を構成している。また、光源１と直角プリズム１３との間の光路中には、直角プリズム１３の近傍に照度分布のほぼ均一な照野を形成するための手段、すなわち直角プリズム１３の近傍の照度分布をほぼ均一化するための照度均一化手段として、フライアイレンズ１１とコンデンサーレンズ１２とが配置されている。

【0068】

こうして、直角プリズム１３により分割された一方の光束は、回折光学素子２０ａを含む第１光学系（１４ａ～２５ａ）およびマイクロフライアイレンズ６を介して、二次光源４０の円形状の面光源（照明瞳面において光軸ＡＸを含む第１領域に位置する光強度分布）４０ａを形成する。一方、直角プリズム１３により分割された他方の光束は、第１光学系（１４ａ～２５ａ）とは異なる光路に沿って、回折光学素子２０ｂを含む第２光学系（１４ｂ～２５ｂ）およびマイクロフライアイレンズ６を介して、二次光源４０の４極状の面光源（照明瞳面において光軸ＡＸから離れた第２領域に位置する光強度分布）４０ｂを形成する。

【0069】

ここで、回折光学素子２０ａ（２０ｂ）は、第１光学系（第２光学系）の光路中に配置されて入射する光束を第１領域の円形状の面光源４０ａ（第２領域の４極状の面光源４０ｂ）に対応する光束に変換するための第１光束変換素子（第２光束変換素子）を構成している。また、マイクロフライアイレンズ６は、第１光束変換素子としての回折光学素子２０ａからの光束および第２光束変換素子としての回折光学素子２０ｂからの光束に基づいて、その後側焦点面またはその近傍（すなわち照明瞳面）に二次光源（照明瞳分布）４０を形成するためのオプティカルインテグレータを構成している。

【0070】

さらに、第１光束変換素子としての回折光学素子２０ａ、第２光束変換素子としての回折光学素子２０ｂ、およびオプティカルインテグレータとしてのマイクロフライアイレンズ６は、円形状の面光源（すなわち照明瞳面上の第１領域に位置する光強度分布）４０ａと、４極状の面光源（すなわち照明瞳面上の第２領域に位置する光強度分布）４０ｂとを有する二次光源（照明瞳分布）４０を形成するための照明瞳形成手段を構成している。また、コンデンサー光学系８および結像光学系１０は、オプティカルインテグレータとしてのマイクロフライアイレンズ６からの光束を被照射面であるマスクＭへ導くための導光光学系を構成している。

【0071】

また、上述したように、第１アキシコン系としての円錐アキシコン系２３ａとズームレンズ（変倍光学系）２４ａとは、第１光学系（１４ａ～２５ａ）の光路中に配置されて円形状の面光源（第１領域）４０ａの形状を変更するための第１形状変更手段を構成している。同様に、第２アキシコン系としての円錐アキシコン系２３ｂとズームレンズ（変倍光学系）２４ｂとは、第２光学系（１４ｂ～２５ｂ）の光路中に配置されて４極状の面光源（第２領域）４０ｂの形状を変更するための第２形状変更手段を構成している。

【0072】

さらに、上述したように、偏光状態変更部１７ａ（１７ｂ）において、１／２波長板１７ａｂ（１７ｂｂ）は、第１光学系（第２光学系）の光路中に配置されて入射する直線偏

光の偏光方向を必要に応じて変化させるための第１位相部材（第２位相部材）を構成している。また、デポラライザ１７ａｃ（１７ｂｃ）は、第１光学系（第２光学系）の光路に対して挿脱自在に構成されて、入射する光を必要に応じて非偏光化するための第１偏光解消素子（第２偏光解消素子）を構成している。

【0073】

また、１／４波長板１７ａａ（１７ｂａ）は、第１光学系（第２光学系）の光路中に配置されて入射する楕円偏光の光を直線偏光の光に変換するための位相部材を構成している。こうして、偏光状態変更部１７ａは、第１光学系の光路中に配置されて第１領域の円形状の面光源４０ａを通過する光束の偏光状態を変更するための第１偏光状態変更手段を構成している。一方、偏光状態変更部１７ｂは、第２光学系の光路中に配置されて第２領域の４極状の面光源４０ｂを通過する光束の偏光状態を変更するための第２偏光状態変更手段を構成している。

【0074】

また、上述したように、ミラー３、ミラー駆動部４、フライアイレンズ１１、コンデンサーレンズ１２、および直角プリズム１３は、直角プリズム１３における光量分割比を変化させ、ひいては第１光学系へ導かれて第１領域の円形状の面光源４０ａを通過する光束の光強度（光量）と第２光学系へ導かれて第２領域の４極状の面光源４０ｂを通過する光束の光強度（光量）との比を変更するための光強度比変更手段を構成している。

【0075】

こうして、本実施形態では、円錐アキシコン系２３ａおよびズームレンズ２４ａを有する第１形状変更手段と、円錐アキシコン系２３ｂおよびズームレンズ２４ｂを有する第２形状変更手段との作用により、第１領域の円形状の面光源４０ａの形状と第２領域４極状の面光源４０ｂの形状とを互いに独立に変更する制御を行うことができる。また、偏光状態変更部１７ａを有する第１偏光状態変更手段と、偏光状態変更部１７ｂを有する第２偏光状態変更手段との作用により、第１領域の円形状の面光源４０ａを通過する光束の偏光状態と第２領域の４極状の面光源４０ｂを通過する光束の偏光状態とを互いに独立に変更する制御を行うことができる。

【0076】

換言すれば、第１形状変更手段と第２形状変更手段と第１偏光状態変更手段と第２偏光状態変更手段とは、第１領域の形状と第２領域の形状とを互いに独立に変更する制御と、第１領域を通過する光束の偏光状態と第２領域を通過する光束の偏光状態とを互いに独立に変更する制御とを行うための照明瞳制御手段を構成している。さらに、本実施形態では、ミラー３、ミラー駆動部４、フライアイレンズ１１、コンデンサーレンズ１２、および直角プリズム１３を有する光強度比変更手段の作用により、第１領域の円形状の面光源４０ａを通過する光束の光強度と第２領域の４極状の面光源４０ｂを通過する光束の光強度との比を変更する制御を行うことができる。

【0077】

以上のように、本実施形態の照明光学装置（１〜１０）では、様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件、たとえば二次光源の形状や光強度や偏光状態などに関して多様性に富んだ照明条件を実現することができる。また、本発明の露光装置では、様々な特性を有するマスクパターンを忠実に転写するために必要な適切な照明条件を実現することができるので、マスクのパターン特性に応じて実現された適切な照明条件のもとで良好な露光を行うことができる。

【0078】

なお、上述の実施形態では、回折光学素子２０ａおよび２０ｂが光路に対して挿脱可能に構成され、且つ特性の異なる他の回折光学素子と交換可能に構成されている。したがって、第２光学系中の４極照明用の回折光学素子２０ｂに代えて、たとえば２極照明用（８極照明用）の回折光学素子を光路中に設定することによって、３極（９極）照明を行うことができる。また、第２光学系中の４極照明用の回折光学素子２０ｂに代えて、たとえば輪帯照明用の回折光学素子を光路中に設定することによって、変形輪帯照明を行うことが

できる。

【0079】

また、第１光学系中の円形照明用の回折光学素子２０ａに代えて、たとえば４極照明用の回折光学素子２０ｂを光路中に設定することによって、８極照明を行うことができる。同様に、第１光学系中の円形照明用の回折光学素子２０ａや第２光学系中の４極照明用の回折光学素子２０ｂに代えて、適当な特性を有する回折光学素子を光路中に設定することによって、様々な形態の変形照明を行うことができる。さらに、４極照明用の回折光学素子２０ｂを光路から退避させて円形照明を行ったり、円形照明用の回折光学素子２０ａを光路から退避させて４極照明を行ったりすることもできる。

【0080】

また、上述の実施形態では、直角プリズム１３により分割された一方の光束が第１光学系（１４ａ～２５ａ）へ導かれ、直角プリズム１３により分割された他方の光束が第２光学系（１４ｂ～２５ｂ）へ導かれている。しかしながら、これに限定されることなく、分割素子を介して分割された光束を第１光学系および第２光学系とは異なる光路に沿って第３光学系を介して照明瞳面上の第３領域へ導く構成も可能である。

たとえば、第１光学系（１４ａ～２５ａ）によって照明瞳面上の第１領域内に、図３に示した面光源４０ａを形成し、第２光学系（１４ｂ～２５ｂ）によって照明瞳面上の第２領域内に、図３に示した面光源４０ｂ１，４０ｂ４を形成し、これら第１光学系および第２光学系とは異なる第３光学系（不図示）によって照明瞳面上の第３領域内に、図３に示した面光源４０ｂ２，４０ｂ３を形成する構成として、面光源４０ａに達する光束の偏光状態を非偏光、Ｘ方向偏光またはＺ方向偏光に設定し、面光源４０ｂ１，４０ｂ４に達する光束の偏光状態を光軸を中心とした円の接線方向に偏光面を持つ直線偏光に設定し、面光源４０ｂ２，４０ｂ３に達する光束の偏光状態を光軸を中心とした円の接線方向に偏光面を持つ直線偏光（面光源４０ｂ１，４０ｂ４に達する光束の偏光方向とは直交する方向に偏光面を持つ直線偏光）に設定することもできる。

【0081】

図７は、本実施形態の第１変形例にかかる制御ユニットの構成を概略的に示す図である。第１変形例の制御ユニット５０は、図２に示す実施形態の制御ユニット５と類似の構成を有する。しかしながら、第１変形例では、ズームレンズ２４ａおよび２４ｂとマイクロフライアイレンズ６との間の構成だけが、図２の実施形態と相違している。以下、図２の実施形態との相違点に着目して、第１変形例の制御ユニット５０の構成および作用を説明する。

【0082】

図７を参照すると、第１変形例の制御ユニット５０では、ズームレンズ２４ａを介して第１光学系（１４ａ～２４ａ）から射出された光束が、偏向部材としての直角プリズム（あるいは折り曲げミラー）２７により＋Ｚ方向に反射される。直角プリズム２７により＋Ｚ方向に反射された光束は、リレーレンズ系２８を介して、第２光学系の光軸上に配置された偏向部材としての直角プリズム（あるいは折り曲げミラー）２９に入射する。直角プリズム２９により＋Ｙ方向に反射された第１光学系からの光束は、リレーレンズ系３０を介して、マイクロフライアイレンズ６に達する。

【0083】

一方、ズームレンズ２４ｂを介して第２光学系（１４ｂ～２４ｂ）から射出された光束は、直角プリズム２９に遮られることなく、リレーレンズ系３０を介して、マイクロフライアイレンズ６に達する。なお、第１変形例では、円錐アキシコン系２３ａ（２３ｂ）と、直角プリズム２７の反射面と、直角プリズム２９の反射面と、マイクロフライアイレンズ６の入射面とが、光学的にほぼ共役になっている。また、所定面２２ａ（２２ｂ）と、リレーレンズ系２８の瞳面と、リレーレンズ系３０の瞳面と、マイクロフライアイレンズ６の後側焦点面（あるいは射出面）とが、光学的にほぼ共役になっている。

【0084】

そして、直角プリズム２７と２９とは、分割素子である直角プリズム１３と照明瞳面で

あるマスクＭとの間の光路中に配置されて、第１光学系（１４ａ〜２４ａ）の光軸と前記第２光学系（１４ｂ〜２４ｂ）の光軸とを合成するための合成素子を構成している。第１変形例においても上述の実施形態と同様に、第１領域の円形状の面光源４０ａの形状と第２領域４極状の面光源４０ｂの形状とを互いに独立に変更する制御、第１領域の円形状の面光源４０ａを通過する光束の偏光状態と第２領域の４極状の面光源４０ｂを通過する光束の偏光状態とを互いに独立に変更する制御、および第１領域の円形状の面光源４０ａを通過する光束の光強度と第２領域の４極状の面光源４０ｂを通過する光束の光強度との比を変更する制御を行うことができる。

【0085】

図８は、本実施形態の第２変形例にかかる制御ユニットの要部構成を概略的に示す図である。第２変形例の制御ユニット５１は、図２に示す実施形態の制御ユニット５および第１変形例の制御ユニット５０と類似の要部構成を有する。しかしながら、第２変形例では、ミラー３と偏光状態変更部１７ａおよび１７ｂとの間の構成が、図２の実施形態および第１変形例と相違している。以下、図２の実施形態および第１変形例との相違点に着目して、第２変形例の制御ユニット５１の構成および作用を説明する。

【0086】

図８を参照すると、第２変形例の制御ユニット５１では、ミラー３により＋Ｙ方向に反射された光束が、ビームスプリッター３１に入射する。ビームスプリッター３１により−Ｚ方向に反射されて第１光学系へ導かれた光束は、折り曲げミラー３２により＋Ｙ方向に反射された後、少なくとも１つの減光フィルター３３ａを介して、偏光状態変更部１７ａに達する。一方、ビームスプリッター３１を透過して第２光学系へ導かれた光束は、少なくとも１つの減光フィルター３３ｂを介して、偏光状態変更部１７ｂに達する。偏光状態変更部１７ａおよび１７ｂよりも後側（マイクロフライアイレンズ６側）の構成は、図２の実施形態または第１変形例と同じである。

【0087】

ここで、減光フィルター３３ａおよび減光フィルター３３ｂが光路に対して挿脱可能に構成され、且つ特性の異なる他の減光フィルターと交換可能に構成されている。すなわち、減光フィルター３３ａは、第１光学系の光路に対して選択的に挿脱自在な少なくとも１つの減光手段であって、第１光学系の光路中に配置されて第１領域の円形状の面光源４０ａを通過する光束の光強度を変更するための第１光強度変更手段を構成している。また、減光フィルター３３ｂは、第２光学系の光路に対して選択的に挿脱自在な少なくとも１つの減光手段であって、第２光学系の光路中に配置されて第２領域の４極状の面光源４０ｂを通過する光束の光強度を変更するための第２光強度変更手段を構成している。

【0088】

したがって、第２変形例では、ミラー３を傾動させるためのミラー駆動部４は不要である。そして、たとえばビームスプリッター３１における光量分割比を１：１に設定し、減光フィルター３３ａや減光フィルター３３ｂを特性の異なる他の減光フィルターと交換したり、減光フィルター３３ａや減光フィルター３３ｂを光路から退避させたりすることにより、図２の実施形態または第１変形例とは異なり、第１領域の円形状の面光源４０ａを通過する光束の光強度と第２領域の４極状の面光源４０ｂを通過する光束の光強度とを互いに独立に変更する制御を行うことができる。

【0089】

上述の各実施形態または各変形例において、照度均一化手段としてのフライアイレンズ１１に替えて、そのファーフィールド（またはフラウンホーファー回折領域）にほぼ均一な光強度分布を形成する回折光学素子を適用してもよい。ここで、この回折光学素子のファーフィールド（またはフラウンホーファー回折領域）は、照度均一化手段としてのコンデンサーレンズ１２の後側焦点位置またはその近傍にリレーされることになる。

【0090】

また、上述の各実施形態または各変形例において、第１光学系（１４ａ〜２５ａ）および第２光学系（１４ｂ〜２５ｂ）中の回折光学素子２０ａ（２０ｂ）からズームレンズ２

４ａ（２４ｂ）までの光学系を、たとえば特開２００１－１７６７６６号公報に開示される照明光学装置の回折光学素子５１からズームレンズ７までの光学系や、特開２００１－８５９２３号公報に開示される照明光学装置のマイクロレンズアレイ４からズームレンズ７までの光学系、特開２００２－２３１６１９号公報に開示される回折光学素子４からズームレンズ７までの光学系、特開２００３－１７８９５１号公報に開示される照明光学装置の回折光学素子４からズームレンズ７までの光学系、特開２００３－１７８９５２号公報に開示される照明光学装置の角度光束形成部２から変倍光学系４までの光学系などに置き換えることも可能である。

【0091】

上述の実施形態にかかる露光装置では、照明光学装置によってマスク（レチクル）を照明し（照明工程）、投影光学系を用いてマスクに形成された転写用のパターンを感光性基板に露光する（露光工程）ことにより、マイクロデバイス（半導体素子、撮像素子、液晶表示素子、薄膜磁気ヘッド等）を製造することができる。以下、上述の実施形態の露光装置を用いて感光性基板としてのウェハ等に所定の回路パターンを形成することによって、マイクロデバイスとしての半導体デバイスを得る際の手法の一例につき図９のフローチャートを参照して説明する。

【0092】

先ず、図９のステップ３０１において、１ロットのウェハ上に金属膜が蒸着される。次のステップ３０２において、その１ロットのウェハ上の金属膜上にフォトレジストが塗布される。その後、ステップ３０３において、上述の実施形態の露光装置を用いて、マスク上のパターンの像がその投影光学系を介して、その１ロットのウェハ上の各ショット領域に順次露光転写される。その後、ステップ３０４において、その１ロットのウェハ上のフォトレジストの現像が行われた後、ステップ３０５において、その１ロットのウェハ上でレジストパターンをマスクとしてエッチングを行うことによって、マスク上のパターンに対応する回路パターンが、各ウェハ上の各ショット領域に形成される。その後、更に上のレイヤの回路パターンの形成等を行うことによって、半導体素子等のデバイスが製造される。上述の半導体デバイス製造方法によれば、極めて微細な回路パターンを有する半導体デバイスをスループット良く得ることができる。

【0093】

また、上述の実施形態の露光装置では、プレート（ガラス基板）上に所定のパターン（回路パターン、電極パターン等）を形成することによって、マイクロデバイスとしての液晶表示素子を得ることもできる。以下、図１０のフローチャートを参照して、このときの手法の一例につき説明する。図１０において、パターン形成工程４０１では、上述の実施形態の露光装置を用いてマスクのパターンを感光性基板（レジストが塗布されたガラス基板等）に転写露光する、所謂光リソグラフィー工程が実行される。この光リソグラフィー工程によって、感光性基板上には多数の電極等を含む所定パターンが形成される。その後、露光された基板は、現像工程、エッチング工程、レジスト剥離工程等の各工程を経ることによって、基板上に所定のパターンが形成され、次のカラーフィルター形成工程４０２へ移行する。

【0094】

次に、カラーフィルター形成工程４０２では、Ｒ（Red）、Ｇ（Green）、Ｂ（Blue）に対応した３つのドットの組がマトリックス状に多数配列されたり、またはＲ、Ｇ、Ｂの３本のストライプのフィルターの組を複数水平走査線方向に配列したカラーフィルターを形成する。そして、カラーフィルター形成工程４０２の後に、セル組み立て工程４０３が実行される。セル組み立て工程４０３では、パターン形成工程４０１にて得られた所定パターンを有する基板、およびカラーフィルター形成工程４０２にて得られたカラーフィルター等を用いて液晶パネル（液晶セル）を組み立てる。

【0095】

セル組み立て工程４０３では、例えば、パターン形成工程４０１にて得られた所定パターンを有する基板とカラーフィルター形成工程４０２にて得られたカラーフィルターとの

間に液晶を注入して、液晶パネル（液晶セル）を製造する。その後、モジュール組み立て工程４０４にて、組み立てられた液晶パネル（液晶セル）の表示動作を行わせる電気回路、バックライト等の各部品を取り付けて液晶表示素子として完成させる。上述の液晶表示素子の製造方法によれば、極めて微細な回路パターンを有する液晶表示素子をスループット良く得ることができる。

【0096】

なお、上述の実施形態では、露光光としてＫｒＦエキシマレーザ光（波長：２４８ｎｍ）やＡｒＦエキシマレーザ光（波長：１９３ｎｍ）を用いているが、これに限定されることなく、他の適当なレーザ光源、たとえば波長１５７ｎｍのレーザ光を供給するF_2レーザ光源などに対して本発明を適用することもできる。さらに、上述の実施形態では、照明光学装置を備えた露光装置を例にとって本発明を説明したが、マスクやウェハ以外の被照射面を照明するための一般的な照明光学装置に本発明を適用することができることは明らかである。

【0097】

また、上述の実施形態において、投影光学系と感光性基板との間の光路中を１．１よりも大きな屈折率を有する媒体（典型的には液体）で満たす手法、所謂液浸法を適用しても良い。この場合、投影光学系と感光性基板との間の光路中に液体を満たす手法としては、国際公開番号ＷＯ９９／４９５０４号公報に開示されているような局所的に液体を満たす手法や、特開平６－１２４８７３号公報に開示されているような露光対象の基板を保持したステージを液槽の中で移動させる手法や、特開平１０－３０３１１４号公報に開示されているようなステージ上に所定深さの液体槽を形成し、その中に基板を保持する手法などを採用することができる。

【0098】

なお、液体としては、露光光に対する透過性があってできるだけ屈折率が高く、投影光学系や基板表面に塗布されているフォトレジストに対して安定なものを用いることが好ましく、たとえばＫｒＦエキシマレーザ光やＡｒＦエキシマレーザ光を露光光とする場合には、液体として純水、脱イオン水を用いることができる。また、露光光としてF_2レーザ光を用いる場合は、液体としてはF_2レーザ光を透過可能な例えばフッ素系オイルや過フッ化ポリエーテル（ＰＦＰＥ）等のフッ素系の液体を用いればよい。

【図面の簡単な説明】

【0099】

【図1】本発明の実施形態にかかる露光装置の全体構成を概略的に示す図である。

【図2】図１における制御ユニットの内部構成を概略的に示す図である。

【図3】マイクロフライアイレンズの後側焦点面またはその近傍に形成される５極状の二次光源を概略的に示す図である。

【図4】二次光源を構成する４極状の面光源に対する円錐アキシコン系の作用を説明する図である。

【図5】５極状の二次光源に対する円錐アキシコン系とズームレンズとの協働作用を説明する図である。

【図6】図１の偏光モニターの内部構成を概略的に示す斜視図である。

【図7】本実施形態の第１変形例にかかる制御ユニットの構成を概略的に示す図である。

【図8】本実施形態の第２変形例にかかる制御ユニットの要部構成を概略的に示す図である。

【図9】マイクロデバイスとしての半導体デバイスを得る際の手法のフローチャートである。

【図10】マイクロデバイスとしての液晶表示素子を得る際の手法のフローチャートである。

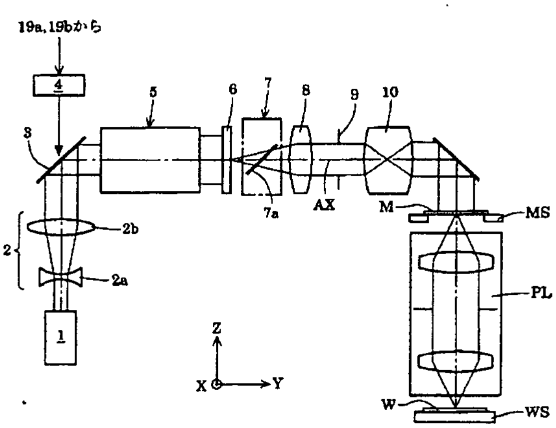
【符号の説明】

【0100】

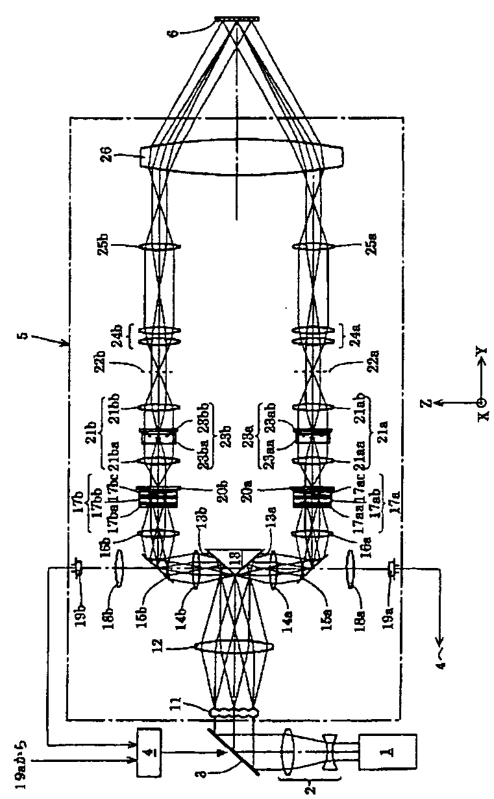
１　光源

５，５０，５１　制御ユニット
６　マイクロフライアイレンズ（フライアイレンズ）
７　偏光モニター
７ａ　ビームスプリッター
８　コンデンサー光学系
９　マスクブラインド
１０　結像光学系
１１　フライアイレンズ
１３　直角プリズム（分割素子）
１７　偏光状態変更部
１９　検出器
２０　回折光学素子（光束変換素子）
２１　アフォーカルレンズ
２３　円錐アキシコン系
２４　ズームレンズ
２６　集光光学系
Ｍ　マスク
ＰＬ　投影光学系
Ｗ　ウェハ

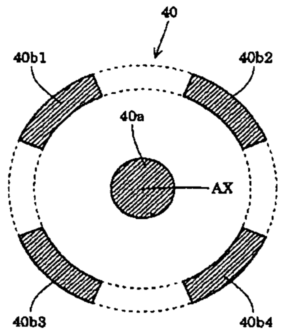
【図1】



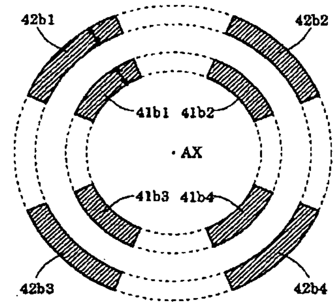
【図2】



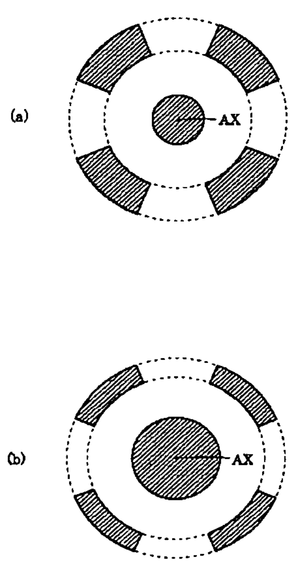
【図3】


40
40b1
40b2
40a
AX
40b3
40b4

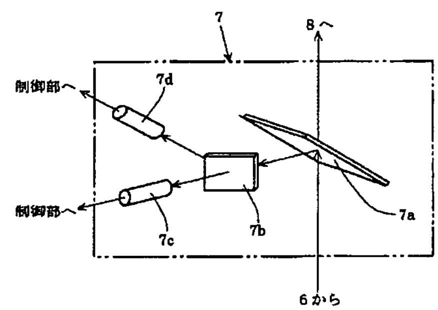
【図4】


42b1
42b2
41b1
41b2
AX
41b3
41b4
42b3
42b4

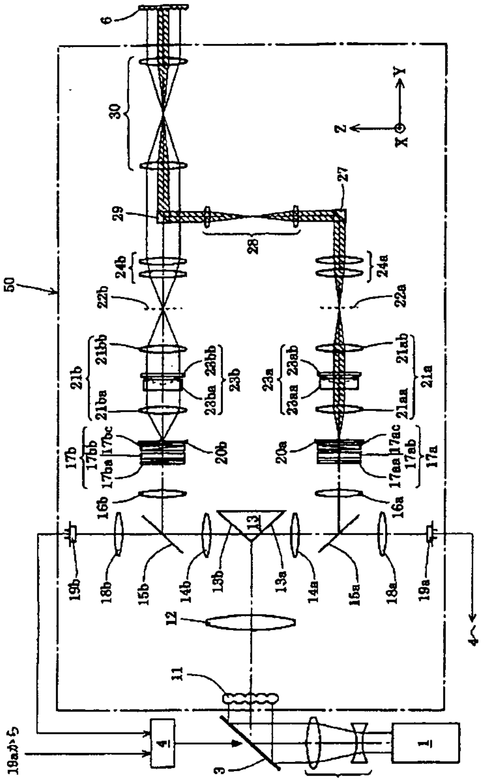
【図5】


(a)
AX
(b)
AX

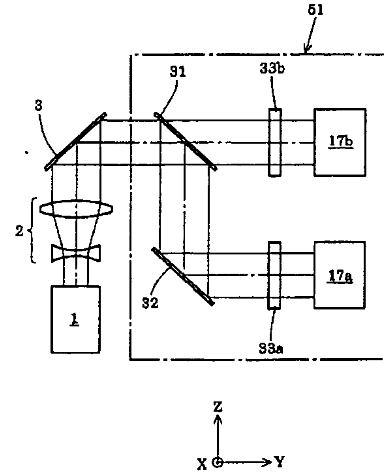
【図6】


7
8へ
制御部へ
7d
制御部へ
7c
7b
7a
6から

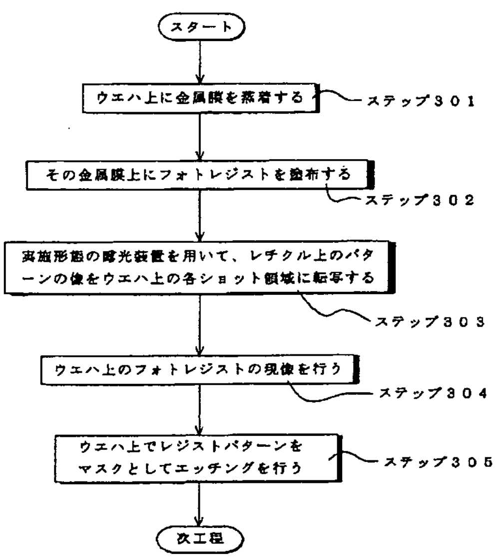
【図7】



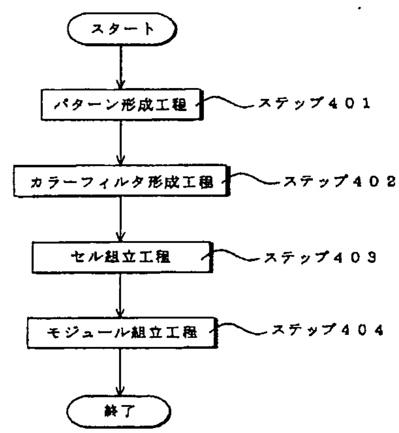
【図8】


51
31
33b
3
17b
2
17a
1
32
33a
Z
X
Y

【図9】


スタート
ウエハ上に金属膜を蒸着する
ステップ３０１
その金属膜上にフォトレジストを塗布する
ステップ３０２
実施形態の露光装置を用いて、レチクル上のパターンの像をウエハ上の各ショット領域に転写する
ステップ３０３
ウエハ上のフォトレジストの現像を行う
ステップ３０４
ウエハ上でレジストパターンをマスクとしてエッチングを行う
ステップ３０５
次工程

【図10】


スタート
パターン形成工程
ステップ４０１
カラーフィルタ形成工程
ステップ４０２
セル組立工程
ステップ４０３
モジュール組立工程
ステップ４０４
終了